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CITRUS AND SUBTROPICAL FRUIT RESEARCH

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C & R-PREP.

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

There is included under each problem area in the report, a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research. Also included is a brief description of related work conducted by private organizations. No details on progress of State station or industry research are included except as such work is cooperative with U.S.D.A.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last two years. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
December 1, 1962

OTHER COMMODITY AND FUNCTIONAL REPORTS

A progress report similar to this one is prepared for use by each of the following research and marketing advisory committees:

Cotton and Cottonseed	Sheep and Wool
Dairy	Sugar
Deciduous Fruit and Tree Nut	Tobacco
Forage, Feed and Seed	Vegetable
Forestry	Economics
Grain	Farm Equipment and Structures
Livestock	Food and Nutrition
Oilseeds and Peanut	Food Distribution
Potato	Home Economics
Poultry	Soils, Water and Fertilizer
Rice	Transportation and Storage

Two additional reports of progress are prepared in order to make available the complete research program. They are:

Ornamentals and Other Miscellaneous Commodities
Other Research — Cross Commodity

ORGANIZATIONAL UNIT REPORTS

All of the material in the commodity and functional reports listed above is the same as that found in the 20 division and 3 service research reports listed below.

Agricultural Research Service (ARS)

Agricultural Engineering
Animal Disease and Parasite
Animal Husbandry
Crops
Entomology
Soil and Water Conservation
Utilization -- Eastern
Utilization -- Northern
Utilization -- Southern
Utilization -- Western
Human Nutrition
Clothing and Housing
Consumer and Food Economics

Agricultural Marketing Service (AMS)

Market Quality
Transportation & Facilities

Economic Research Service (ERS)

Farm Economics
Marketing Economics
Economic & Statistical Analysis
Foreign Development and Trade
Analysis
Foreign Regional Analysis

Other Services

Farmer Cooperative Service (FCS)
Forest Service (FS)
Statistical Reporting Service (SRS)

A copy of this report or any of the others listed above may be requested from Roy Magruder, Executive Secretary, Citrus and Subtropical Fruit Research and Marketing Advisory Committee, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

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INTRODUCTION

This report deals with research on citrus and subtropical fruits such as orange, grapefruit, lemon, avocado, papaya, mango, and leitchi. It covers Farm Research, Utilization Research, Marketing Research, Economic Research, and Nutrition and Consumer-Use Research of the U.S.D.A. and cooperating agencies. Only a brief description of the related work of the State Experiment Stations and industry is included.

Under each of the Problem Areas there is a statement describing the Program of work underway and the professional man-years devoted to the major kinds of research included. The relative scope of the total research effort on citrus and subtropical fruits is indicated by the approximate number of professional man-years employed: 113 by the U.S.D.A., 127 by the State Experiment Stations, and about 300 by industry and other organizations.

A brief report of Progress and significant findings for U.S.D.A. and cooperative programs is given for each phase of the research program.

A considerable amount of basic cross-commodity and functional research that will supply new knowledge applicable to the citrus and subtropical fruit problems is not included in this report. Such research is included in the functional reports such as "Economics," "Soils, Water and Fertilizer," and in the "Other Research" report.

Research by U.S.D.A.

The farm research comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insects, and crop harvesting and handling operations and equipment. This research is conducted by the Crops, Entomology and Agricultural Engineering Divisions of the Agricultural Research Service; and in fiscal year 1962 involved 51 professional man-years.

Utilization research deals with methods of preservation of these commodities through canning, drying, freezing, or combinations of these methods and also with the origination of new forms of food products or combinations of citrus and subtropical fruits with other foods. It is concerned with improved equipment and processes. The work is done at the Western Utilization Research and Development Division, Albany, California; at the WURDD laboratory at Pasadena, California; at the U. S. Fruit and Vegetable Products laboratories of the Southern Utilization Research and Development Division at Weslaco, Texas, and Winter Haven, Florida; and in cooperation with the industry and other organizations mentioned under Program for each research area. In fiscal year 1962, the work involved 36 professional man-years.

Marketing research involves the physical and biological aspects of assembly, packaging, transporting, storing and distribution from the time the product leaves the farm until it reaches the ultimate consumer. The work reported herein is conducted by the Market Quality and Transportation and Facilities Research Divisions of the Agricultural Marketing Service and utilized 17 professional man-years in fiscal year 1962.

Economic research is concerned with marketing costs, margins and efficiency; market potential, supply and demand; outlook and situation; and improving marketing through research with farmer cooperatives. The work reported herein is done by the Economic and Statistical Analysis and the Marketing Economics Research Divisions of the Economic Research Service; by the Standards and Research Division of the Statistical Reporting Service, and by the Marketing Division of the Farmer Cooperative Service. Approximately 8 professional man-years were devoted to this work in fiscal year 1962.

Nutrition and consumer-use research pertains to composition and nutritive value; physiological availability of nutrients and their effects; and new and improved methods of preparation, preservation and care in homes, eating establishments and institutions. This work is done by the Divisions of Human Nutrition Research and Consumer and Food Economics Research of the Agricultural Research Service, and in fiscal year 1962 involved 1.5 professional man-years.

Research by State Experiment Stations

There is included under each Problem Area a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research.

Consolidating this information for the entire field of interest, we find that in fiscal year 1962 a total of 127 professional man-years were spent by the State Agricultural Experiment Stations on citrus and subtropical fruits.

Citrus and subtropical fruits research in 1962 was in progress in six State Agricultural Experiment Stations; namely, California, Florida, Texas, Louisiana, Puerto Rico, and Hawaii. A total of 127 professional man-years were devoted to research which could be labeled as being directly on citrus and subtropical fruits. Of this, 91 man-years were production research--breeding, variety evaluation, culture, and disease and insect control. Twenty man-years were related to utilization, processing, and product development; and 14 man-years were related to research on maintaining quality during the marketing process. A considerable amount of economic research is underway on citrus and subtropical crops, but much of this is across-the-board and

combined with all fruits and vegetables. It is likely that economic research related specifically to citrus and subtropical crops would amount to about 12 professional man-years in addition to the 127 cited above. The economic research includes studies of the cost and returns from the production of these fruits. In the marketing area it includes studies of demand, costs of processing, cost of handling and selling, and the trends in market structure and organization.

No details on progress of State station research are included in this report except as such work is cooperative with U.S.D.A.

Research by Industry and Other Organizations

The 300 professional man-years estimated as industry's participation in research on citrus and subtropical fruits are employed primarily by food processors and distributors, food industry and trade associations, food container and equipment suppliers (over half the total is in these three categories), marketing equipment and facility manufacturers, chemical and fertilizer companies, package and container manufacturers, market research institutes and corporations, nurserymen, orchardists, and grove owners.

A number of food processing companies and wholesale and retail distributors are presently conducting research in various phases of products and process development in frozen, canned, and dried citrus and subtropical fruit products. These studies cover a wide field directed toward the securing of patents or secret processes that can be exploited rather quickly to the best interests of each company.

The canning, freezing and dehydrating industries each maintain an association with a technical staff and either do research in their own laboratories or support research at U.S.D.A. laboratories, universities and other organizations. Some of their research is of a basic nature, but most of it is of an applied nature and the results are made available in trade and scientific journals.

Allied industries and suppliers to the food processing industry maintain excellent laboratories and large research staffs to provide technical information to the industry. Most of their research is of a trouble-shooting nature although many valuable contributions to the store of basic knowledge have been made by this group.

Marketing equipment and facility manufacturers also make sizeable contributions to research on the development of equipment for handling fruits on the farm or orchard, into and out of packing houses, transportation vehicle, wholesale distribution center and in the retail establishment, as well as research on the containers in which it is moved and on the transportation vehicles from which it moves from one point in the distribution channel to another.

Chemical and fertilizer companies are significant factors in research on the development of new materials or combinations of materials to produce more efficiently, high quality fruits through better nutrition of the growing plant, control of diseases, insects, nematodes, weeds and the regulation of growth processes through use of growth regulator substances such as fruit set thinners, stop-drop chemicals, bloom retarders, etc.

Market research institutes and others in marketing economics research are largely concerned with research in consumer preference, market potentials, market promotion and development, and interregional and intermarket competition. The results are available only to the purchaser.

A number of the larger nurserymen spend considerable time and money in the search for, and testing of, new varieties of citrus and subtropical fruits in the major production areas; sometimes on their own acreage, but usually in cooperation with some grower.

It is very difficult to estimate the contribution of growers to our overall research effort on citrus and subtropical fruits. Certainly, in the field of production his help is indispensable for most of the laboratory research results must finally be confirmed by orchard scale experiments. The grower cooperates with the U.S.D.A., State Experiment Stations and suppliers of many materials and equipment--usually, without compensation except for the experience and knowledge gained. Citrus growers in Arizona, California, Florida and Texas are conducting research in such areas as flat land, reclamation, cultural practices, fertilization, tree spacing, hedging, rootstock evaluation, clonal studies, and are actively cooperating the Department and State Experiment Stations by propagating and testing seedlings, crosses and new varieties.

Industry cannot be expected to conduct basic work which is remote from its profit objectives. However, basic research done by the Department and States will be utilized by industrial research laboratories in the further development of improved products and equipment. Industry's cooperation in supporting research on citrus and subtropical fruits in the form of grants, gifts or loans of materials, equipment and facilities at Federal and State stations has contributed greatly to its success.

No details on progress of industry research are included in this report except as such work is cooperative with U.S.D.A.

I. FARM RESEARCH

CITRUS AND SUBTROPICAL FRUIT CULTURE, BREEDING AND GENETICS, DISEASE INVESTIGATIONS AND VARIETY EVALUATION Crops Research Division, ARS

Problem. Citrus has assumed a place of necessity in the health and diet of the American public. To maintain this position more information is needed on the factors which influence successful and economic production. More precise information is needed on the interrelation between climatic factors and growth, cold hardiness and production; on the absorption processes and functions of various elements needed in growth and the effects of soil salinity, alkalinity and high water retention on growth; on various diseases and methods to control them. New rootstocks are needed which induce more cold hardiness in tops, are disease and nematode tolerant, tolerant to high soil alkalinity, salinity, poor drainage and which induce high yield of high quality fruit. New top varieties are needed with greater cold hardiness, greater disease resistance, better fruit quality, a widespread in season of maturity, suitable both for fresh market and processing.

USDA PROGRAM

The Department has a continuing long-term research program involving plant pathologists, physiologists, horticulturists and plant breeders carrying on both basic and applied studies to enable growers to increase both production and quality. Crosses are made at Orlando, Florida and Indio, California but not at Weslaco, Texas and progenies are evaluated at all three locations; disease studies are carried on at all three federal stations; basic physiology studies of cold hardiness are centered at Weslaco, with variety and hybrid progenies evaluated for cold hardiness at all three stations; rootstock evaluation on a field basis is centered in Florida but preliminary evaluation of hybrid rootstock progenies and certain species for cold hardiness, salt tolerance, and disease resistance is carried on at all three stations; basic nutrition is carried on principally in Florida but some work is also done in Texas and California. Climatology is carried on in Florida, Texas, Arizona and in several locations in California; the work in Arizona and California is in cooperation with the Agricultural Experiment Stations. Airpollution studies are carried on in California under contract with the University of California at Riverside. Basic studies on minor element nutrition and factors affecting dormancy are under way in Israel, on the interaction of strains of the Tristeza Virus in Brazil and on citrus dieback in India under P.L. 480 Projects.

The Federal scientific effort devoted to research in this area totals 18.6 man years. Of this number, 1.6 is devoted to breeding; diseases 5.8; culture 7.7; variety evaluation 1.5; program leadership .5; and crop introduction and evaluation 1.5.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 69.1 professional man years. Of this number 15.1 were in breeding and genetics; 13.1 diseases; variety evaluation 6.3 and 34.6 in culture. Florida, California, Arizona, Texas, Hawaii, Louisiana and Puerto Rico are conducting studies on citrus and subtropical plants. The breeding programs are designed to produce improved varieties adapted to diverse climatic and soil conditions. The induction of mutations is under investigation and basic studies are carried on to determine the inheritance of desired characters. Considerable work is underway to develop improved varieties of avocado, papaya, macadamia, mango, guava, and coffee. The program includes research on virus, fungus, nematode and bacterial diseases. Virus diseases, particularly Tristeza psorosis, exocortis and stubborn are under intensive research in California: nematodes are important problems in both California and Florida, where the devastating burrowing nematode is causing serious damage. Root rots are serious on most tropical plants; intensive work on avocado root rot is underway in California. Fruit rots both in the orchard and in transit are continuing problems which are difficult to solve; transit and storage rots such as blue and green molds, and lemon brown rot, are under intensive study in California; fruit rots of dates, avocado, pineapple spoilage, coffee fusarium disease and bacterial disease of banana are under study in California, Florida, Hawaii and Puerto Rico.

Four experiment stations (Arizona, California, Florida and Texas) are conducting extensive studies on fertilization of citrus, soil management and soil moisture, pruning etc. and some work is done in Louisiana. Some work particularly in Florida is designed to tailor trees for mechanical harvesting. Extensive studies are underway in California on rootstocks for citrus and avocado. Both Hawaii and Puerto Rico have extensive work on coffee, papaya, guava, passion fruit and pineapple to determine better methods of propagation, and culture.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Crop Introduction and Evaluation

For use and evaluation in the rootstock testing and breeding program, 105 citrus introductions were obtained by international exchange.

At Miami a block of about 100 Arue avocado seedlings have been screened for cold resistance. In such studies two- to three-year-old seedlings have been found more satisfactory than younger plants.

Indications to date suggest that cold resistance may be vegetatively correlated with leaf size and internode length. Several plants out of the 100 screened have been selected for further study

Six selections of jujube have been made for further testing out of several thousand seedlings grown from the 5 introduced varieties maintained at Chico. Since indications are that three of these have a greater potential for the production of desirable seedlings, additional populations are being made from them for selection.

B. Breeding

1. In California, 24 new hybrids were selected for second tests; 10 are loose-skinned tangerine types of high fruit quality; 5 are Satsuma hybrids of possible value as parents for breeding cold-hardy mandarins; one is a seedling of Temple orange selfed that may be a virus-free Temple type orange; and another is an open-pollinated seedling of a cross between the trifoliate and sour oranges. Because this seedling has fruit of grapefruit-type, few seeds and good quality, and one very cold-hardy parent, it promises to be a valuable source of cold hardiness for breeding a cold-hardy grapefruit. Budwood of the 1962 selections for a second test is being supplied to the cooperators listed in the 1961 report and in addition to The Kern County Land Co., Bakersfield, California, and to Laflin Date Gardens, Thermal, California.

Approximately 1/3 of the 5000 hybrid seedlings planted last year on the Brock Ranches Experimental Farm, East Mesa (Imperial County, California) were killed in the January 1962 freeze. These will be replaced by hybrids produced in the 1961 crosses now growing in the greenhouse at Indio.

A new series of 14 crosses of scion varieties were attempted in 1961. In 6 of these, Temple or Umatilla tangors were used as seed parents crossed with sweet oranges. 1500 seeds were sent to the Weslaco station and a similar number plus about 1000 seed of a Robinson tangeline X Orlando tangelo cross made in Orlando, Florida, were planted in the greenhouse at Indio. In 16 crosses of rootstock types the objects were the production of hardy, salt-tolerant stocks; the combination of boron and chloride tolerance (Rangpur lime X C. macrophylla), and production of semi-dwarfing cold-hardy stocks. Trifoliate orange was used in 11 crosses and Rangpur Lime in 5. The number of hybrids in seed lots obtained from rootstock crosses is not yet known.

Breeding efforts in Florida in 1961 were concentrated on crosses that had the dual objective of producing improved scion varieties and supplying information concerning self-sterility. In 16 types

of crosses a total of 11,790 blossoms were hand pollinated. The evidence yielded by this work clearly indicates that Robinson tangerine fruit set was very greatly increased by the use of Orlando tangelo pollen.

Small progeny families from open-pollinated seedlings of several hundred F₁ hybrids of rootstock types are under test in the field in California to determine percentage of nucellar seedlings produced; tolerance to high-lime soil; tolerance to salinity or cold hardiness. Many of these F₁ hybrids have been rogued as a result of poor performance of their seedlings.

Crosses in Florida for production of new rootstocks were limited to five types involving commercially-desirable and disease-resistant types as parents. This included hand pollination of an additional 1515 flowers.

In Texas limited numbers of crosses were made in 1961 involving Temple orange, Satsuma, citrumelo 4481, limequat, and shaddock as seed parents.

Pollen parents included red grapefruit, Marrs orange, Orlando tangelo, Chinotto orange, and Changsha mandarin. These seedlings, with 1961 crosses of Indio and Orlando, are now in the greenhouse and will be planted in the field in 1962. Many seedlings from crosses made at Indio and Orlando in 1960, budded on sour orange or on their own roots, survived the January 1962 freeze. These involved parents such as trifoliate hybrids, Changsha mandarin, Ichang pummelo, Kara and Kunembo mandarins, satsumas, and other mandarin hybrids and thus further demonstrate their greater cold tolerance as compared to grapefruit and sweet orange varieties in commercial culture in Texas.

During the fall of 1961, seedlings of 453 citrus varieties and species from the Hiawassee farm, Orlando, Florida, were grown in the greenhouses preparatory to establishing virus free nucellar clones of these varieties. These seedlings are now at the Foundation Farm and will be planted to establish a new virus free variety collection.

2. In California a long-term date breeding project is underway. Four back-crosses were made in 1961. The seedlings have been slow in coming into flower, possibly because of continued inbreeding. Inter-varietal crosses were made on Barhee and Dayri with pollen from Deglet Noor BC-3.

C. Diseases

1. Foot rot. In California screening of seedlings from open pollinated species and varieties and from controlled crosses has been continued to find more root rot tolerant individuals. Four hundred selections from

67 lots screened in 1961 have been retained for further study. Seedlings from open pollinated hybrids of Sunki mandarin x Swingle trifoliate orange showed good tolerance to root rot; cuttings of such seedlings were rooted for second test and 23 showed high tolerance and have been propagated for fruiting. Forty-five selections from tolerance screening tests made in 1960 have been propagated and will be inoculated on the trunk with Phytophthora cultures using the bark patch technique.

In Florida various citrus selections including 69 of rough lemon from the Florida Department of Agriculture collection were inoculated with Phytophthora parasitica using the California aerated water bath technique and all were found non tolerant. Twelve selections were made from the rough lemons on the basis of their ability to regenerate new roots.

Microscopic studies in Florida of Phytophthora water-bath infected roots of sweet orange, rough lemon, sour orange, and trifoliate orange failed to show any basic difference in the host-parasite relationship which would account for the differential tolerance of these species in the field. However, seedling of the various rootstock varieties when planted in infested soil showed a gradient in reaction from the most tolerant to least tolerant as follows: Sunshine Tangelo, rough lemon, trifoliate orange, sour orange, carrizo citrange, Cleopatra mandarin, and sweet orange. It is obvious that a better technique is needed.

In Florida intensive studies to determine the etiology of foot and root rot have yielded only Phytophthora parasitica. P. citrophthora has been isolated from fruits but never from roots; in California citrophthora is a common root parasite. There has been considerable variation among isolates of parasitica; cultures have been sent to Dr. M. E. Gallegly at the University of West Virginia for positive identification.

Where Orlando tangelo trees on rough lemon rootstock were interset in an old orchard in Florida having a history of root rot and foot rot, trees planted in locations where the soil had been treated with Captan, Manzate or Parsate outgrew checks.

2. Virus diseases of citrus. Tristeza and stem pitting of citrus have been studied in Florida and Brazil. In Florida spread of tristeza has been observed in Pinellas, Polk, and Brevard Counties, as well as in Orange and Lake Counties. The increase in tristeza spread has been related to increases in aphid populations. Some distribution of tristeza has resulted from budwood distribution from parent trees that have become naturally infected since the period of initial testing. The State Department of Agriculture in their Budwood Certification Program is now retesting parent trees on an annual basis.

In Florida field trees inoculated in 1959 with severe, strong, and mild strains of tristeza virus were examined. Those inoculated with the severe strain begin to show some stunting and upright leaves in the

crowns. Trees inoculated with the mild and strong strains do not yet show any definite symptoms. In the greenhouse Duncan and Leonardy grapefruit seedlings inoculated with the severe strain are stunted and yellow. Eureka lemon seedlings inoculated with the severe strain have died. All plants inoculated with strong and mild strains have survived and show only slight stunting as compared with the healthy control plants.

In Brazil the stem-pitting of Pera orange trees continues to be a real problem. Research under Public Law 480 has been initiated to determine the interaction of virus strains and whether mild strains will give protection against the more severe ones.

Heat treatment of citrus virus-infected plants has been continued for obtaining tristeza-free budwood of valuable hybrid progenies in the citrus breeding program which became naturally infected. Several valuable selections otherwise lost have been recovered. The heat treatment has not proved to be effective against xyloporosis virus. Plants heat treated at 100°F for 360 days are still carrying the xyloporosis virus.

Tests for tristeza were carried out on 78 varieties that exist as unbudded seedling trees at the Hiawassee farm variety collection in Orlando, Florida. Of this list 65 varieties were found to be free from tristeza, as indicated by the Key lime test. Budwood of the tristeza-free nucellar varieties were taken to the Foundation Farm.

3. Infectious variegation. In Florida infectious variegation in juice was reported in 1961. Transmission was effected from citrus to citrus and also to cowpea, crotalaria and cucumber. It has been found that certain lines of black cowpeas react to show local lesions whereas the virus is systemic in other lines of black cowpeas. These results are useful in studying properties of the virus such as ageing in vitro, tolerance to dilution both with water and chemicals. Investigations have been carried out on variations in virus titer in relation to time lapse after inoculation. This is the first time a citrus virus has been transmitted mechanically. All attempts to transmit other citrus viruses using the same technique have failed.

4. Stubborn disease. In California the comparative pathological and horticultural studies of stubborn disease in lines of Marsh grapefruit on Rough lemon rootstock have shown, at 4 years of age, that only the 2 seedling lines of Marsh, originated in 1955, are free of stubborn disease. The trees have just begun to fruit, therefore this conclusion is based principally on growth habit. The other 9 infected lines, including the Frost nucellar line, 2 good old lines and 6 previously suspected stubborn-affected lines, all have from 30 to 50 per cent of the trees showing symptoms of stubborn disease in their growth habit and in the fruit. Some trees are already of no commercial value. No good indicator plant has been found for stubborn disease among 50

species and varieties of Citrus and allied genera inoculated 4 to 6 years ago with 2 lines of the stubborn disease virus.

5. Dancy mandarin decline. The numerous cases of decline in Dancy Mandarin trees, a new disorder in California that has occurred in the past year, suggests that this disorder is becoming serious and requires study. In exploratory studies in cooperation with the Extension Service and the University of California at Riverside, the disorder has been shown unrelated to the tristeza, vein enation, or psorosis viruses and not consistently associated with fungus infections, high nematode populations, salinity, rootstock, or adverse soil type.

6. Florida blight. Blight, an old disorder of unknown etiology, continues to kill many trees in Florida groves. A study of the roots of blight affected trees in cooperation with nematology to investigate the possibility of nematode involvement was undertaken. Blight areas in 7 groves were mapped, root samples collected and examined for nematode species and populations. No nematode was found consistently associated. All the samples have as yet been examined histochemically.

In the course of examining roots for nematodes, a low type of fungus (appears to be a species of Physoderma or Urophlyctus) was found more prevalent in roots of Blight trees than in the roots of adjacent healthy appearing trees. This same organism was generally present in the trunk and small branches of Blight trees but only occasionally was found in the above-ground portions of healthy appearing trees. Detection of the organism in citrus tissues proved to depend on rather precise staining procedures. Experiments to determine the pathogenicity of this organism are incomplete but it is believed to be a very promising lead in the solution of the cause of Blight.

7. Spreading decline. All field plantings of burrowing nematode-tolerant rootstocks survived the moderate winter freeze of 1961-62 in Florida in good condition. Six have been lined out at the Foundation Farm, Florida, for use in line project CR g4-3. Arrangements are now being made with the Postal Colony and Minute Maid Corp. to use the tolerant rootstocks as interplants in commercial groves which are suffering from spreading decline to determine their tolerance under grove conditions in naturally infested soil.

Three nurserymen now have lining out stock of all the burrowing nematode-tolerant varieties, and these stocks are being budded with virus free certified budwood of various sweet orange and grapefruit varieties. Nursery trees on the tolerant rootstocks will be available to the industry for experimental plantings in 1963. In order to determine the variation among seedlings, large-scale screening of individual rootstock candidates is being carried out in a nematode-infested tank. The best selections of Rough lemon-A and Rough lemon-B, Sanguine Grosse Ronde sweet orange and Pineapple-156 are being propagated for seed production. Carrizo citrange from

California, demonstrated to be the best of the three Carrizo citrange sources studied, is being screened to select seedlings most vigorous and most tolerant to the burrowing nematode.

Wide scale screening to find additional burrowing nematode tolerant citrus varieties and relatives have been continued. The blood strain of Valencia, East Highlands-Winn 58-7 Sweet, Hi-ho Sweet from California, Algerian and Cuban navel oranges from Florida have shown promising tolerance in the tank test. Unfortunately, Citrumelo 4475, which carries *Phytophthora* tolerance shows little tolerance to the burrowing nematode.

All of the Clone-X seed produced last year has been budded with commercial sweet orange scions and will be planted in the grove owned by the person on whose property Clone-X was discovered. This use of 600 Clone-X seedlings will give us valuable performance on this most interesting rootstock candidate.

In order to combine the screening program for both nematode tolerance and *Phytophthora* tolerance, a new separate tank for the burrowing nematode, the citrus nematode, for *Phytophthora*, and a tank of steamed soil have been constructed. These tanks will be used to grow identical series thus enabling evaluation of resistance to each entity.

A study of the crowns of a number of nematode-tolerant and nematode-resistant rootstocks as seedlings indicated that *Fusarium* could be recovered from these crowns in a large number of cases. However, the presence of *Fusarium* in the crowns of these tolerant and resistant plants seems to exert no effect upon their growth, in marked contrast to the severe damage caused by *Fusarium* in Duncan grapefruit, which is not tolerant to the nematode.

Tissue relations of Burrowing Nematode. Burrowing nematodes reared in aseptic tissue cultures were used to study the movement of the burrowing nematode in and out of root tissues. It was surprising to learn that the female nematodes penetrate the living excised okra roots, lay their eggs, and then leave the roots. Apparently penetration of the roots takes place for egg-laying purposes, but the nematodes soon migrate from the roots and move about in the agar. The use of excised root tissue was found to be a good method of studying the biological activities of plant-parasitic nematodes.

Bio-control studies now indicate that the morphogenic material which is produced by nematodes in culture and which causes ring and knob formation in nematode-capturing fungi is found in relatively large amounts within the nematode body itself. Techniques have now been worked out for isolating material directly from the nematodes. The morphogenic substance called "Nemin" described by Pramer has been isolated by simply collecting nematodes grown in broth cultures on double thickness filter paper, boiling the filter paper/nematodes

mixture for two minutes, cooling and filtering the liquid material through a bacteriological filter to remove nematodes, eggs, and bacteria. Nemin can be concentrated from the nematode extract therefore characterization of the active components of this material should be made considerably simpler. Another source of Nemin has been discovered in a fungus-feeding nematode, Aphelenchoides sacchari. Blocks of agar containing the nematode and the fungus placed directly on growing cultures of predaceous nematode-capturing fungi develop a capturing response in 24 hours. This response is often so vigorous that within 48 hours no living nematodes remain in the petri dish where the fungus was observed. Cultures of this nematode can be used as a tool for screening fungi for their nematode capturing ability.

8. Avocados. The rootstock planting is comprised of 3-year-old trees of 3 scions of West Indian, Mexican (Diaz), Lula and Guatemalan rootstocks. Sunblotch symptoms developed only in Lula tops and R-1 tops, but not in 29-9 tops, of trees on Diaz rootstocks. Diaz and 29-9 varieties are thus suspected to be symptomless carriers of sunblotch virus. Trees in this planting were severely damaged in the January 1962 freeze.

D. Varietal Evaluation

1. Varietal evaluation studies are limited almost entirely to testing of nucellar clones of old varieties and to recently released new hybrids introduced by the Department, from State Experiment Stations and by private growers. The work involves determination of productivity, quality, pollination requirement, rootstock adaptation, disease resistance and cold hardiness under different regional environments.

In Texas budded trees from 27 new hybrid selections, introduced as budwood from Indio, were set out at Weslaco, Monte Alto and Carrizo Springs. Seedlings of varieties, introduced as seed from California and Japan, were added to the variety collection for evaluation for cold hardiness and fruiting characters. Of 13 Mandarin hybrids from the breeding work in Florida planted at Weslaco, the selection Bower, was outstanding. Seventeen nucellar clones of early maturing standard varieties were compared for juice, color, acid, and brix in November through January and those from the variety Parson Brown were superior.

Twelve virus free rootstock and fruit varieties were introduced into Arizona during 1961 from the indexed stocks at Indio, California for establishment at the Tempe and Yuma citrus stations.

2. In Florida trees of 2 persian lines have been propagated on 8 rootstocks in preparation for orchard test plantings. These lines were selected from seedlings grown from rare seeds found in persian lines; all tests have indicated that they are nucellars, and are free of virus, thus may serve as foundation material to replace the present infected stocks.

E. Culture

1. Citrus fruit set. No work at Orlando, Weslaco, or Indio.
2. Citrus rootstocks. In the 1961 report a very brief summary was presented on a major rootstock trial in Florida on Lakeland fine sand, showing the superiority of Rough lemon over the other 6 rootstocks in the test in total yields of fruit produced. The mass of data from this long-term experiment has now been carefully analyzed and has yielded important information on the trends in production with increasing tree age and in pounds of solids produced in comparison with total yield of fruit. Up to 13 years of age, Rough lemon greatly exceeded all other rootstocks in boxes of fruit produced. During the following 4 years, however, grapefruit, Cleopatra, and sweet orange rootstocks caught up with Rough lemon in the case of the Parson Brown scion variety, and with Valencia as the scion variety they approached Rough lemon. Rusk citrange, although it made smaller trees, produced about the same amount of fruit as the sour orange rootstocks. On a pound-solids basis Rough lemon outyielded the other rootstocks in both scion varieties during the first 13 years of age. Thereafter, the Cleopatra, grapefruit, and sweet orange rootstocks equaled the Rough lemon in pound-solids produced in the Parson Brown scion variety and in the Valencia these 3 rootstocks surpassed Rough lemon.

In January 1962, a rootstock field trial was planted near Wauchula, Florida, on typical "flatwood" type soil. The planting consists of Hamlin sweet orange, nucellar strain as the scion variety on 26 rootstocks, all trifoliate hybrids except Rough lemon and Sour orange which serve standards for comparison. Very large acreages of citrus are being planted and will continue to be planted on the flatwood soils of Florida. The need of specific rootstock information for such soils is urgent.

In Texas six-year-old nucellar red grapefruit trees on 11 different rootstocks were bigger than comparable virus-infected old-line trees. However, fruit yield of the nucellar trees was less than that of old-line trees on all except 2 virus-sensitive rootstocks. Many trees in the experimental planting were damaged by freeze of January 1962. Trees on Cleopatra mandarin rootstock showed less injury than those on 10 other rootstocks; nucellar trees were damaged less than old-line trees.

In a rootstock test of old-line 12-year-old Valencia trees in Texas, virus-free trees were bigger and yielded more fruit than trees with 2 viruses--exocortis and xyloporosis. Differences were slight on sour orange and Cleopatra mandarin rootstock and greater on other rootstocks sensitive to the 2 viruses.

3. Cultural treatments of citrus. The results of a 3-year investigation of the relation of rootstock, frequency of irrigation and frequency of fertilization to growth and establishment of grapefruit trees on fine

sands of low fertility and water-holding capacity under hot California desert climatic conditions showed that the critical factor was water supply. Fertilization more often than once a month was not needed, and good trees could be produced on any of the 4 common stocks used. During summer, however, maintenance of soil moisture tensions below 0.4 to 0.5 bar by irrigation once or twice a week was of vital importance for rapid growth of trees. The experiment was terminated in the fall of 1961 and the results are being prepared for publication.

4. Mineral nutrition of citrus. Although considerable study has been given to the fertilization of bearing-sized citrus, virtually no information is available for young trees. Grower practices are highly variable and many young trees are killed or severely injured each year from excessive fertilizer. In order to gain evidence on the optimal type of mixtures, rates, and times of application, a series of field tests have been conducted in Florida over the past five to six years. Tests have been made in widely separated areas of Central Florida with large experiments involving from 30 to 90 separate treatments. In addition to various combinations of essential minerals, the studies included the effect of liming, nutritional foliage sprays and the use of water-holding materials such as colloidal phosphate and vermiculite around the root basins. The studies showed that while some phosphorus is desirable, a combination such as 8-2-8 is more appropriate than the common mixture of 4-7-5 and fits all soil types in the main citrus-growing areas. It was also shown that very frequent feeding of young trees is not necessary. Three or four light applications the first year and two thereafter gave growth response equal or superior to more. Both the optimal number of feedings and the rates now used are about one-half that which has long been used or needed.

The use of liming materials on new land is beneficial to tree growth, but the tests showed that this need could be supplied by using dolomitic lime as a filler in the mixed fertilizer instead of sand, which has long been used. Planting materials such as colloidal phosphate were sometimes beneficial the first year but the effect disappeared during the second and third year and does not appear to justify the extra time and expense required. Nutritional sprays of both major and minor elements were of no benefit when these elements were contained in the soil applications. Slowly available synthetic organic nitrogen was found to be satisfactory but no better than all soluble inorganic nitrogen.

Potassium deficiency symptoms, in the field in Florida, for the first time were found in a potash-rate experiment on Marsh grapefruit. The main results of this test were discussed in the 1960 report. However, in the seventh and eight years many of the trees on low potash developed a peculiar chlorosis of the foliage; analysis of such leaves showed extremely low leaf K content. In early stages this

often resembled the deficiency pattern of manganese. Later stages somewhat resembled magnesium deficiency. As a whole, however, the chlorotic pattern was distinctive and should be useful in future diagnosis of malnutrition troubles.

The disappearance of heavy metals in Florida light, sandy soil as mentioned last year was studied in glass leaching columns. It was found that the organic-free subsoil has very low retentive power for the metal elements. Thus, soil-applied metals are apt to be lost by the leaching of one year's rainfall if they are applied in ionic form and plowed under. The topsoil, which differs from the subsoil only by the one-to two-per cent organic matter, effectively holds copper, zinc, and manganese against leaching. The big problem here is that the metals don't move far enough down to reach the root zone. Thus, new tests that involve placing insoluble forms of the metals in the subsoil are of great potential interest for future grove management if they prove successful.

Work continues on the study of organic acid metabolism of leaves and fruit. The current interest is the seasonal changes in acids and the effect that different levels of nutrition have on them. The point of greatest interest so far is that developing fruit contain relatively little citric acid prior to juice development. Through the spring and early summer, malic is the dominant acid.

5. Cold hardiness of citrus. A severe freeze hit the Rio Grande Valley of Texas January 9 to 12, 1962. Minimum temperatures ranged from 19°F at Brownsville to 12°F at Monte Alto, Texas. Weslaco had a low of 16°F. The entire citrus fruit crop in the Rio Grande Valley still remaining on the tree was completely frozen. This included all Valencia oranges, more than half the grapefruit, and a few early oranges. Some oranges were salvaged for concentrate, but essentially all the grapefruit were lost. Tree injury will vary considerably. Essentially all the foliage was lost Valley-wide. Young 1-2 year old trees, banked, were killed to the banks, but the trees will survive. Trees 3-6 years old, unbanked, have been killed. Trees 8 years old or older vary in injury, but many trees are dead back to 2-3" wood. Estimates on total trees lost from the freeze are still premature, but as the picture looks now perhaps a 30-40% loss may be seen. Fruit production in 1962-63 will be very slight.

Hundreds of young seedlings of many citrus species, varieties, and hybrids were in the field during the Texas freeze, and these have been evaluated for cold-hardiness. Poncirus trifoliata and its hybrids were by far the most cold hardy, followed by the mandarins, oranges, grapefruit, and lemons and limes. Numerous Japanese types and Clementine mandarin X Temple orange hybrids showed no cold-hardiness.

Although the freeze interrupted field cold-hardiness studies, controlled environment studies have continued in growth chambers. Young Red Blush grapefruit seedlings were exposed to 60°F. by day temperatures and 40°F. night temperatures for 6 weeks. As the cool temperature exposure period progressed, plants increased in cold-hardiness. This hardiness was associated with an increase in dormancy and no increase in cell sap concentration was noted. Evidence suggested that the plants did not increase in cold-hardiness by a mechanism similar to that of cabbage and other plants which truly cold-harden.

Nine month-old seedlings of 24 citrus cultivars and 6 related species were exposed to constant 70°F. day temperatures and variable lower night temperatures up to 38 weeks. Trifoliate orange, Nagami kumquat, False Hybrid satsuma mandarin, and Yuma citrange ceased growth at 57-60°F. night temperatures, Changsha mandarin and Severinia buxifolia at 50-57°F., Red Blush grapefruit, sour orange, citranges, and citrumelos at 48-50°F., and limes, lemons and Citrus macrophylla below 48°F. Cultivars exhibiting bud dormancy at a relatively higher night temperature showed greater cold hardiness when exposed to freezing temperatures. Cold hardiness appeared correlated with the degree of dormancy exhibited. Young seedlings of different citrus cultivars and related species exhibited relatively the same dormancy and cold-hardiness characteristics as have large trees of the same kind. The results also suggest a possible procedure whereby hybrid citrus materials might be screened at a young age for dormancy and cold-hardiness characteristics.

6. Salt tolerance of citrus. In Texas one-year-old Red Blush grapefruit trees grown in soil in crocks in the greenhouse were irrigated with water containing various sodium and calcium salts. Chloride accumulation, bronzing and burning of the leaves on the mature terminal flushes, were greatest with the CaCl_2 treatment followed by NaCl and Na_2SO_4 , in order. Chlorosis in the new flush was greater with the CaCl_2 treatment followed by Na_2SO_4 and NaCl , in order.

Following the salt regime, the above plants were hardened for 2 weeks at 43°F. nights and 62°F. days and then subjected to a freezing treatment of 23°F. for 4 hours. The freeze injury was greatest on the CaCl_2 cultures, followed by NaCl , Na_2SO_4 and controls, in order.

Eight blocks with nucellar Red Blush on 16 rootstocks per block were set out in the field at Rio Farms and 4 blocks were irrigated with canal water and 4 blocks irrigated with Rio Farms' saline well water. All trees were given a freezing treatment of 23°F. for 4 hours in December 1961, with the portable tree freezer. Leaf injury was

generally severe on all trees regardless of rootstock and irrigation treatment, while twig injury was ranged from none to severe, depending on the rootstock and irrigation treatment. Twig injury was greater on well water cultures than on the canal water cultures on trees on sour orange, Siamelo shaddock, Morton citrange, Excelsa, Butnal sweet lime, Gambu, and Columbian sweet lime rootstocks. Twig injury was equal for both irrigation treatments on trees on Macrophylla, Cleopatra mandarin, Rough lemon, Sunki mandarin and Shekwasha. Twig injury was less on the well water cultures than on the canal water cultures of trees on Rangpur lime, Iran lemon, and Precoce sweet orange.

7. Citrus climatology. Phenological stations at Orlando and Claremont, Florida; Monte Alto, Texas; Tempe, Arizona; and Indio, Riverside and Santa Paula, California; were in operation all year, making the second consecutive year of these operations. By recording the microclimate of trees concomitantly with making biweekly measurements on tree behavior, the phenological work provides a mechanism for studying the effects on bearing trees in commercial orchards under varied climatic conditions, such as the freezes in Florida, Texas and California, a drought in Florida, and a hurricane in Texas. In regard to the effects of freezing on citrus, the difficulty that has been encountered in field observations in the past is the lack of accurate records on temperatures within the tissues of the plant and precise experiments to determine how freezing occurs under natural conditions. Such accurate information is a necessary precursor for more precise information in programmed climates as planned in the cold-hardiness investigations.

The temperature of leaves shaded by other leaves, in the phenological experiments, was generally about the same as the temperature of the ambient air as measured by the Foxboro recording thermometer located in a ventilated shelter in a missing-tree space within the grove. This applies to high summer temperatures during the day as well as to low winter temperatures at night. However, the temperature of outside leaves exposed to the sky frequently was elevated 20°F. or above that of the ambient air. At Indio during the summer months ambient air temperatures during the day were frequently above 110°F. and the temperature of leaves exposed to the sun often rose to above 130°F. Leaves on the south side of the tree were hardened by frequent exposure to such temperatures and did not burn as readily as unhardened leaves on the northwest side of the tree. Such unhardened leaves burned after one day's exposure during May or June when the sun on long days swung around to the northwest.

A study was made of the temperature of outside leaves of various positions on the tree in order to arrive at meaningful thermometer locations. Leaf temperatures at 1, 3, 6, 12, 15 and 20 feet from the ground on the south side of the tree during the heat of the day were fairly uniform, but that at 3 feet from the ground was the highest.

The temperature of outside leaves at the 6-foot level did vary considerably around the tree from north to south; the warmest position in these tests at Orlando was on the southwest side.

Leaf, fruit, twig and trunk temperatures of 30-year-old Valencia orange trees were recorded during 3 freezes during the past winter: at Orlando on December 30, at Monte Alto on January 9-12, and at Indio on January 12. At Orlando the ambient air at 6 feet from the ground was below 25°F. for 2 hours and reached a minimum of 22°F. The air was calm and the relative humidity was 100%; a heavy frost resulted. Also, a typical temperature inversion occurred, the air at 20 feet being 10 degrees higher than that at 6 feet. Leaf and twig temperatures dropped 2°F. below the ambient air, but no injury resulted. Fruit temperatures dropped to 24.5°F. and remained at that temperature for one hour; the rise in fruit temperature following this exposure coincided with a rise in temperature of the ambient air. Ice crystals were abundant in the fruit the next morning. Hesperidin crystals were observed in the fruit 2 weeks later, but these disappeared after 2 weeks and no off-flavors were observed. The volume of juice per 100 grams of fruit at the time of the freeze was 55 ml and the concentration of sugar in the juice was 11.1%. The temperature of the bark on the trunk cooled to a low of 28.5 during the freeze.

The ambient air temperatures at the 6- and 20-foot levels during the freeze at Indio were similar to those at Orlando; the minimum was 20.5°F. There was no wind. Leaf, twig and trunk temperatures were similar to those at Orlando. The fruit temperature, however, was lowered to 22°F. for 2 1/2 hours without showing evidence of freezing (no sign of hesperidin crystals). The apparent greater resistance of the fruit at Indio to freezing was associated with a lesser volume of juice than the Orlando fruit. The volume of juice per 100 grams of fruit at Indio was 42.4 ml and the sugar content was the same as the Orlando juice. These trees were slightly more dormant than those at Orlando, which could possibly influence the fruit response.

The freeze at the Monte Alto station was of longer duration and more severe than those at Orlando and Indio. The ambient air temperature at the 6-foot level was below 32°F. for 60 hours, below 20°F. for 9 hours and reached a minimum of 11.5°F. A wind of 25 or more miles per hour accompanied the freeze for the first 2 days and nights and kept leaf and twig temperatures at the same temperature as the air. The air temperature at 6, 20 and 40 foot levels was the same, and the relative humidity was about 30%. The fruit on the first night cooled to 26.3°F. and froze, accompanied by a rise in temperature due to the heat of fusion of water to ice. The volume of juice per 100 gram of fruit was the same as at Orlando. Ice crystals were found in the fruit the next morning. The ambient air, leaf and twig temperature dropped to below 15°F. on the third night. The minimum temperature recorded for the bark of the trunk was 21.3°F. Large branches were

killed on these trees, but the true extent of the damage is not yet evident. The trunk and lateral limbs were probably not killed.

The trees at Indio were probably more dormant than those at the other two stations, as indicated by a tighter bark on the small branches and scaffold limbs. Also, there was less radial growth of small branches during the fall at Indio than at the other 2 stations. However, there was more summer and fall new shoot growth at Indio than at Orlando and Monte Alto and new shoot growth ceased in October at all 3 stations. The trees at Indio were exposed to lower night and day temperatures during November and December than were trees at Orlando and Monte Alto and this somehow resulted in the trees at Indio having more cold hardiness. Soil temperatures during the fall were generally lower at Indio than at the other locations. The leaf moisture content in the fall was similar (55%) at all locations.

8. Dates. Moisture and nutrition relationships. At Indio, California long-term (6 years) irrigation treatments were conducted in cooperation with the Department of Plant Pathology, University of California, Riverside, to determine whether periodic drought influenced the development of *Omphalia* root rot. No significant differences in injury resulted to Deglet Noor palms in inoculated plots under the different irrigation treatments. This indicates that periodic drought is not, as had been previously supposed, a critical factor in the development of severe damage by *Omphalia* root rot.

9. Dates. Fruit thinning. In a long-term bunch thinning experiment to determine the relation of crop load to fruit quality, trees were thinned to 40, 60, 80 or 100% of the bunches produced. The results in 1961 follow the general trend of previous years. There was very slight improvement in size and grade of fruit from heavy thinning (40%, 60%), but the yield of trees thinned to 40% of the bunches was only 2/3 that of trees carrying 100% of the bunches produced. This experiment continues to demonstrate the folly of heavy thinning of Deglet Noor dates.

Since dates are hand pollinated, the dilution of viable pollen with dead pollen offers a means of thinning the fruit on the strands sufficiently to greatly reduce the hand labor now expended in thinning. In a young Medjool planting inflorescences pollinated with 1% live pollen set fruit sparsely but not well spaced on the strands. Fruit size was nearly doubled, but yields were low on the trees pollinated with diluted pollen. Work on this method of thinning is being continued in 1962.

10. Dates. Salt tolerance. In the second season of a test of the salt tolerance of mature palms in full bearing, salt was applied to plots of Halawy and Medjool dates at rates designed to produce salinity

conditions classed by the U. S. Salinity Laboratory, Riverside, California as medium, high and very high. These conditions correspond respectively to conductivities of the saturation extract of the soil (in mmhos/cm at 25°C.) of 6-8, 12-16 and 16-24. In the growing season of 1961 leaf growth was measurably reduced under conditions of very high salinity; yield of fruit was progressively decreased from lowest to highest salinity, but fruit size and grade was not significantly affected by salt concentration within the range of the salinity levels used. Because of the difficulties and expense involved in conducting tests on full grown palms, this experiment was terminated after the 1961 harvest and the results are being prepared for publication. Off shoots were planted in 1961 for further salinity tests on dates in small field plots.

11. Dates. Flower and Fruit Development. In 1960 thymadine was added to the chemicals that are being tried to promote offshoot production, but there are still no visible effects from any of the different growth regulators that have been used.

Studies on skin separation in soft dates suggest that separation may be induced by excessive turg in peripheral tissues just as the fruit begins to soften. This would explain increases that have been observed from severe fruit thinning and lends support to reports that skin separation has been increased by excessive soil moisture during ripening.

For the second year studies were made of the effects of number of pickings on grades of Deglet Noor fruit. The results this season, climatically not very different from the previous year, confirm last year's findings that harvesting at one time increases the proportion of dry fruit as compared with 2 or 3 pickings.

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WEED AND NEMATODE CONTROL
Crops Research Division, ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. The losses caused by weeds can be reduced by finding more effective chemical, biological, mechanical, cultural and combination methods of weed control. Improved weed control methods will facilitate farm mechanization, increase production efficiency, and improve the efficiency of the use of human and land resources in agriculture.

Plant-parasitic nematodes occur in all soils used for growing of crop plants and attack all kinds of plants grown for food, forage, fiber, feed, or ornamental purposes. It has been long known that severity of attack by certain fungi is greatly increased if nematodes are present; and nematodes have been known to be the vectors of several plant viruses. There is a need for improvements in the methods of controlling nematodes by crop rotations, cultural practices, chemicals, and biological methods on citrus and subtropical fruits.

USDA PROGRAM

The program of testing herbicides at Tempe, Arizona, involves use of these materials in citrus groves. The Federal scientific effort devoted to basic and applied research on nematodes is 23.5 professional man-years, of which 2.4 is devoted to applied research on citrus and subtropical fruits at Tempe, Arizona; Orlando, Florida; and Weslaco, Texas.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Information on the weed and nematode research for commodities by State Experiment Stations and industry is not available. For a summary statement covering all research by these agencies on weed control, see pages 240 and 241; and on nematode control, see page 276 in the Crops Research Division report.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Weed Control

Weeds in citrus plantings not only compete for moisture and plant nutrients but they may also act as alternate hosts for nematodes and prevent effective control of these organisms. Petroleum oils have been used quite effectively to control weeds in some areas of the West where furrow-irrigation is used. Continuing research stimulated by the need for improved methods has included the evaluation of many

new herbicides for control of weeds in citrus. In experiments at Tempe, Arizona, two applications of diuron per year effectively control summer and winter annual weeds without injuring the crop. Further research in the Southwest and other citrus growing areas is needed to determine the long-term effects of continued use of herbicides.

B. Nematode Control

In greenhouse experiments at Orlando, Florida, it was found that the citrus nematode, Tylenchulus semipenetrans, spreads through soil at a rate of about one-half inch per month and that there is a definite correlation between infection of citrus roots with this nematode and infection with fungus of the genus Fusarium. The combined effect of these two organisms is to reduce root systems.

Also at Orlando, a method for growing citrus seedlings under sterile conditions in the laboratory has been developed and will be used in the future for exact determination of damage caused by nematodes alone and in combination with various fungi. When rough lemon seedlings were infected with burrowing nematodes at Orlando, Florida, either alone, or in combination with Fusarium and Pythium, then grown in the greenhouse for 16 months, green weight was only about 5 grams per plant as compared to an average of 175 grams for uninfected plants, 197 grams for plants infected with Fusarium only and 139 grams for plants infected with Pythium alone. This is in contrast to results previously reported with grapefruit seedlings, where size was reduced only 33% by the nematodes alone and 48% by the combination of nematodes and Fusarium.

In field experiments at Tempe, Arizona, in cooperation with the Arizona Agricultural Experiment Station where grapefruit trees were replanted on sites where old citrus trees had been pulled out due to decline caused by citrus nematodes it was found that there was very little advantage in treatment of the soil with a dichloropropene nematocide before planting. On the other hand, there was a very distinct advantage in applying a dibromochloropropane nematocide in the irrigation water after the trees became established, since any nematodes introduced with the nursery stock are killed by this procedure, and the long waiting period between application of the dichloropropene and planting is eliminated.

Also in a cooperative experiment at Tempe, established in 1958, it has been found that grapefruit trees treated with 4 gallons per acre of dibromochloropropane nematocide (DBCP) were still yielding more and larger fruit and showing better recovery than the controls after four years, whereas, it was necessary to repeat the treatment after two years where only 2 gallons per acre were used. Orange trees

treated with 4 gallons per acre of DBCP in the fall of 1958 still had a very low nematode population on 1961, and yielded an average of 23% more fruit than untreated trees. The increased yield plus the increased fruit size increased the 1961 crop value \$1425 per acre above untreated plots. This was a return of \$37 for every dollar spent on the treatment.

In preliminary experiments at Orlando, Florida, part of the burrowing nematodes and root-lesion nematodes in citrus seedlings were killed by exposure to supersonic energy with no damage to the plants. The range of sound used in these tests was as follows: 790-980 kilo-cycles with 0.7-0.9 amperes of power applied for 30 seconds or two applications of 5 seconds each.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Nematode Control

- Feder, W. A., and Feldmesser, J. 1961. The spreading decline complex. The Separate and combined effects of Fusarium spp. and Radopholus similis on the growth of Duncan grapefruit seedlings in the greenhouse. Phytopathology. 51(10):724-762.
- Feldmesser, J., Feder, W. A., and Rebois, R. V. 1962. Movement of Tylenchulus semipenetrans into rough lemon roots and in soil and its relation to Fusarium in the roots. Phytopathology 52(1):9.

INSECT CONTROL
Entomology Research Div., ARS

Problem. Efficient production of citrus and subtropical fruits depends upon the availability of effective measures for controlling the many insects and mites that attack these crops. Additional research is needed on biological control agents, including parasites, predators, and diseases, and on the integration of biological and chemical control measures. A search for safer, more effective, and more economical insecticides and for other types of insect control methods that will not result in harmful residues on the harvested crops or be detrimental to natural control agents is a continuing necessity. Research on the sterile male technique, attractants, and chemosterilants are among the new approaches that need to be investigated against a number of these pests. Protection against introduction into the United States of tropical fruit flies and other exotic pests requires the availability of effective, low-cost detection methods, quarantine treatments and eradication procedures that can be applied in emergency situations with minimum disturbance of trade or inconvenience to the public. There is constant need for research to improve present control methods and to develop the biological basis needed for their effective application.

USDA PROGRAM

The Department has a continuing program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic and applied research on a variety of problems in this area. Studies on basic biology, physiology and nutrition are carried on at Honolulu, Hilo, and Kahului, Hawaii; Riverside, Calif.; Orlando and Lake Alfred, Fla.; and Weslaco, Tex., in cooperation with the respective State Experiment Stations; at Hoboken, N. J., in cooperation with the Plant Quarantine Division; at Mexico City, Mexico, in cooperation with the Defensa Agricola of the Mexican Secretaria de Agricultura; and at Brownsville, Tex. Research on insecticidal control is carried on at Honolulu, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Weslaco, Tex., in cooperation with the respective State Experiment Stations and at Mexico City, Mexico, in cooperation with the Defensa Agricola of the Mexican Secretaria de Agricultura. Determinations of residues resulting from use of insecticides, including fumigants, are made at Honolulu, Hawaii, and Mexico City, Mexico, and samples from Riverside, Calif., Orlando, Fla., Weslaco, Tex., and Hoboken, N. J., are sent to chemists of the Entomology Research Division,

cooperating States and industry for residue determinations.

Biological control studies at Honolulu, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Weslaco, Tex., are cooperative with the Hawaii, California, Florida, and Texas Experiment Stations and at Mexico City, Mexico, with the Defensa Agricola of the Mexican Secretaria de Agricultura. Insect sterility, attractants, and other new approaches to control are the subject of research at Honolulu, Hawaii (including work on the islands of Guam, Rota, and the Bonin Islands), and at Orlando, Fla., and Mexico City, Mexico, with informal cooperation with local research stations. The evaluation of equipment for insect detection and control is carried on at Hilo and Honolulu, Hawaii, Orlando, Fla., and Mexico City, Mexico, also with informal cooperation with local research stations. Research on insect control treatments for commodities regulated by plant quarantines is the primary responsibility of the laboratory at Hoboken, N. J., in cooperation with the Plant Quarantine Division, aided by the laboratories at Honolulu, Hawaii, and Mexico City, Mexico, in cooperation with the Hawaiian Experiment Station and Defensa Agricola of the Mexican Secretaria de Agricultura, respectively. Research on varietal evaluation for insect resistance, carried on at Honolulu, Hawaii, and Mexico City, Mexico, is cooperative with the Hawaiian and California Experiment Stations and Plant Pest Control and Plant Quarantine Divisions. Research on insect vectors of diseases of citrus at Orlando, Fla., is cooperative with the Division of Plant Industry of the Florida Department of Agriculture and Crops Research Division.

In August 1961, a sublaboratory was established at Agana, Guam, as a base for continuing a practical test of the male sterilization technique for the control of subtropical fruit flies; and in April 1962, a laboratory was established at Weslaco, Tex., in cooperation with the Texas Experiment Station, for research on the brown soft scale on citrus. Facilities for carrying on research have been greatly improved at Orlando, Fla., and in California. New quarters were provided at Riverside, Calif., in January 1961 and personnel transferred there from the station at Whittier, Calif., which was closed at that time.

Additional research (4 professional man-years) is in progress under a grant of P. L. 480 funds to the Plant Protection Department of the Arab Republic, Dokki, Egypt, for studies of induced sterility in males of the Mediterranean fruit fly, Ceratitidis capitata, as a means of controlling and eradicating this pest. In addition, a portion of a grant of P. L. 480 funds (10 professional man-years) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan, is applicable to insects

affecting citrus fruits and to tropical and subtropical fruit fly problems in the United States.

The Federal scientific effort devoted to research in this area totals 29.9 professional man-years. Of this number, 5.6 is devoted to basic biology, physiology and nutrition; 3.4 to insecticidal control; 2.0 to insecticide residue determinations; 2.4 to biological control; 8.2 to insect sterility, attractants and other new approaches to control; 1.0 to evaluation of equipment for insect detection and control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.6 to varietal evaluation of insect resistance; 1.1 to insect vectors of diseases; and 1.6 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 18.3 professional man-years divided among subheadings as follows: Basic biology, physiology, and nutrition 2.9; insecticidal and cultural control 7.8; insecticide residues 2.4; biological control 2.9; insect sterility, attractants, and other new approaches to control 0.2; evaluation of equipment for insect detection and control 1.0; insect control treatments for commodities regulated by Plant Quarantine 0.4; varietal evaluation for insect resistance 0.3; and insect vectors of diseases 0.4. Florida, Texas, and California are conducting research on basic biology, physiology, and nutrition, insecticidal and cultural control, and biological control. Florida and California conduct the bulk of research on insecticide residues, evaluation of equipment for insect detection and control, insect control treatments for commodities regulated by plant quarantines and on insect vectors of diseases. Research on insect sterility, attractants, and other new approaches to control and on varietal evaluation of insect resistance is carried on by California.

Industry and other organizations, including grove owners, conduct research on insect problems on citrus and other subtropical crops. A number of chemical companies develop and supply insect control materials for evaluation by official agencies and some conduct research on insect control directly with growers. Grove owners furnish their plantings and facilities for the conduct of research for insect control. Packing houses furnish fruit and facilities for the development of commodity treatments to permit movement of regulated products under plant quarantines. Estimated annual expenditures by industry are equivalent to approximately 3 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Citrus Insects and Mites. Effective techniques for rearing rust mites are needed to provide colonies for evaluating sterilants, antimetabolites and other biologically active agents. In Florida rearing has been most successful on Murcott honey orange seedlings in air-conditioned greenhouses. High populations were maintained for 9 months on the same group of seedlings without serious damage to plants. Calamondin and Key lime seedlings were not suitable hosts for the rust mite but Temple orange seedlings showed possibilities. Green lemons partially immersed in water were excellent hosts at Riverside, Calif. Excised leaves of lemon, grapefruit and orange on a moist substrate were less satisfactory. Recently, mites have been reared for 6 weeks on green lemons at Orlando, Fla. Calamondin fruit appeared to be an even better host. Exploratory work on the possibility of propagating citrus red mite on an artificial medium has shown that mites will feed through a collodion or some plastic membrane on aqueous solutions of sucrose or agar media containing sucrose. Rearing of the citrus rust mite was not successful in constant temperature rooms held at 80° F. and 70-95% or 30-35% R.H., at Orlando. At Riverside, 80° F. and 70-80% R.H., in a room with a carbon filter was very favorable for rust mite development; continuous low humidity was unfavorable. A fungus disease, Hirsutella, may limit reproduction and development of this mite at high humidity in Florida.

Populations of a pink rust mite that developed in citrus rust mite colonies in the greenhouse at Orlando, Fla., were identified as Aculus pelekassi (Keifer), a species described from citrus in Greece and not previously recorded in the United States. This mite has been found at a few widely scattered locations in Florida, but its economic importance remains to be determined. An albino strain of citrus red mite has been isolated and is being maintained for experimental purposes at Riverside, Calif. Albinism is due to a single recessive gene.

2. Subtropical Fruit Flies. Oriental fruit fly and melon fly abundance remained at high levels throughout the Hawaiian Islands. Approximately 7 million male oriental fruit flies - 490 per trap day - were caught in 39 methyl eugenol traps on four islands during a 12-month period ending March 31, 1962. Nearly $\frac{1}{2}$ million melon fly males - 19 per trap day - and 33,000 Medflies were taken in 65 traps.

Fruit fly hosts producing 10 larvae per pound on one or more islands included guava, false kamani, mango, loquat, peach, rose apple, calamondin, plum, coffee, avocado, mock orange, gourka, apricot, black walnut, English walnut, Surinam cherry, Jerusalem cherry, Barbados cherry, a Solanum sp., white sapote, and Brazilian plum. Mock orange produced 1,540 larvae per pound. Most of the larvae reared from fruits at low elevations were oriental fruit flies. The Medfly was the dominant species in deciduous fruits growing at high, cool locations, and in coffee. Momordica sp. and tomato had the heaviest melon fly infestations.

Breadfruit, a minor host of the oriental fruit fly in Hawaii, where wild preferred hosts are abundant, produced large numbers of these flies on Rota. The oriental fruit fly attacked Pandanus on Rota but not in Hawaii.

Following the interception of a melon fly larva by the Plant Quarantine Division in the blossoms of Sesbania grandiflora, melon flies were found to be strongly attracted to buds and flowers of the plant in Honolulu, Hawaii. Melon flies and oriental fruit flies were reared from field collections. Buds of both pink and white varieties proved to be good hosts in induced oviposition tests. Medfly pupae were also obtained but no emergence occurred. In other induced oviposition tests buds and flowers of red jade, Mucuna novoquinensis, and the sausage tree, Kigelia pinnata, supported development of melon flies. Oriental fruit fly pupae were recovered from the blue-green jade, Strongylodon macrobotry; and both oriental fruit fly and Mediterranean fruit fly pupae were obtained from collections from a sausage tree, but no emergence resulted.

Other new fruit fly infestation records for Hawaii included "Akee" and Blighia sapida, hosts of both the Medfly and oriental fruit fly; Rhudia edulis, host of the oriental fruit fly; and tree tomato, Cyphonandra betacea, host of the Medfly. Japoticaba, Myrciadia cauliflora, produced both oriental fruit flies and melon flies and Java plum, Eugenia cumini, oriental fruit flies in cage tests. Neither produced melon flies. Limeberry, Triphasia trifoliae, an important host of the oriental fruit fly in the Mariana Islands, was highly susceptible to both the oriental fruit fly and the Medfly in Hawaii laboratory tests. Velvet apple, Diospyros discolor, produced melon flies. Cucumbers, Cucumis sativus, exposed simultaneously to melon fly and oriental fruit fly produced both species. Proof is still lacking that prior infestation by the melon fly is a prerequisite for successful establishment of oriental fruit fly infestation in cucumber.

California lemons developed oriental fruit fly infestation when exposed to 25 or more females for 24 hours or longer. Holding the infested lemons for 30 days at temperatures of 56-58° F. and 60-65° R. H. reduced the yield of fruit flies from an average of 0.54 to 0.04 larvae per fruit. All but one of the infested fruits developed green mold and broke down rapidly under the cool storage conditions. These would have been eliminated during normal grading for market. Breadfruit subjected to 2, 4, 8, 16, or 32 female oriental fruit flies for several days, produced 0.5, 8.5, 13.5, 20.1, and 15.7 progeny per female in very uniform fruits. In breadfruit varying in degree of ripeness results were variable. As many as 137 larvae were found to have pupated and emerged inside single fruits from which they could not escape as larvae.

A search for hosts of Anastrepha spatulata, a fruit fly which has been trapped in considerable numbers in Texas in recent years, and for hosts of a closely related species was continued without success, by the Mexican station. Practically all wild fruits available to these species appear to have been investigated.

The annual survey of yellow chapote at 7 ecological stations in northeastern Mexico made in early summer of 1961, disclosed no fruit or very sparse fruiting with light infestation of the Mexican fruit fly. The very low catch of 14 flies in Texas citrus before a severe freeze in January 1962, provides further indication that populations of flies appearing there during the harvest season are probably dependent upon breeding in yellow chapote in Mexico.

Under cage conditions in Hawaii sexual maturity tests with wild and laboratory strains of oriental fruit flies and melon flies indicate that the latter reach sexual maturity at a much younger age. The pairing of wild and laboratory-reared melon flies resulted in a decrease in mating frequency as compared with that of laboratory-reared flies, due in part, it is believed, to delayed sexual maturity of the wild flies.

Additional sex ratio tests confirmed previous results obtained in Hawaii with the oriental fruit fly and the Mediterranean fruit fly, which indicated that reduced mating resulted in a reduction in the number of eggs deposited as well as a reduction in the percent of eggs that hatched. Melon flies produced 90% fewer eggs when there were no males. The percent hatch and total number of eggs deposited by 50 females did not differ significantly when 2, 10, or 50 males were present.

Recent tests in Hawaii with the laboratory, genetically-marked white strain of oriental fruit flies indicate that this strain is compatible with wild oriental fruit flies. The wild strain flies

were far less productive and reach sexual maturity at a later age but the recovery of fertile eggs from reciprocal crosses proved that there was inter-strain mating. A virtually pure white-marked strain of the oriental fruit fly was developed for use in a radiation sterilization experiment on Rota. In genetic studies the white marking behaved as a recessive to yellow. The white flies provide means of quick identification after release and a basis for estimating ratios of sterile to wild flies.

Female oriental fruit flies copulate several times and individual males have fertilized as many as 26 different females in a lifetime. Crosses between white and yellow-marked flies with opportunities for second matings indicated definitely that little additional sperm is deposited in the spermatheca by second matings. Successful insemination of normal females mated previously with unirradiated males may not exceed more than 1 or 2 per female during the first month of life. The testes of normal males remained full of sperm throughout life. The sperm content of irradiated males decreased to a very low level within 30 days. Females that mated first with sterile males were inseminated when mated again with normal males. Females mated first with normal males were less likely to be affected by subsequent matings with sterile males. Size of fly was also not a factor in mating effectiveness.

In the Western Pacific, studies were made of the compatibility of Rota wild flies and a laboratory strain of sterilized flies. The suppressive effect of overflooding in cages at a ratio of 10 sterile flies to 1 normal fly was better than the expected theoretical effect, suggesting that the earlier sexual maturity and greater vigor of the laboratory strain of flies may be more than compensating for the adverse effect, if any, of irradiation on mating and compatibility under cage conditions. Longevity tests in field cages at an altitude of 4700 feet indicated that Medflies reared from Jerusalem cherries will live longer than Medflies reared from peaches or those produced on artificial media in the laboratory.

Improvements were made in fruit fly rearing techniques in Hawaii. Comparisons of the low-cost Type M hydrolyzed protein (\$1.05 per pound) and the high-cost standard MRT (\$7.00 per pound) in the fruit fly rearing medium gave variable results. Differences in humidity control, lighting, etc., may be factors but the diet has been modified to utilize a combination of Type M and MRT protein hydrolysates in a 3:1 ratio with both greater egg deposition and higher percent hatch than obtained with either material alone. Granular dehydrated carrots in the rearing medium were slightly inferior to powdered carrots.

Substitution of granulated vermiculite for sand as a pupation medium permits use of economical, plastic, stackable containers and has the advantages of low weight, less critical moisture requirements, and less tendency for the larvae to escape. Use of vermiculite and cheap soy and yeast hydrolysates will reduce production costs still further. Guava juice diluted with water (2:1) was as effective as undiluted guava juice for wetting the insides of the 1 quart plastic, cylindrical oviposition devices. Four to six of these, each with 300 pin holes, were as effective in cages stocked with 25,000 flies as larger numbers of the cylinders or the use of more holes. In a two-year period production costs for the oriental fruit fly and melon fly have been reduced from \$235 to \$100 per million.

Improvements were also made in rearing methods for the Mexican fruit fly in Mexico. The 15 million larvae produced in the laboratory during the year were largely reared on fresh carrot fortified with brewers' yeast. Dehydrated carrot was adopted as a rearing medium only recently after it was found that addition of yeast hydrolysate results in recovery of larvae equivalent to that obtained with fresh carrot. Increasing males to females in ratios up to 4:1 in breeding cages failed to improve fertility. Cholesterol at 1% added to the fly diet increased oviposition 25% with high fertility and normal adult mortality resulting.

3. Miscellaneous Subtropical Fruit Insects. Trioxa anceps, the leaf gall psyllid of avocado, is a serious pest in many parts of Mexico and may become a problem if it should become established in the United States. Adult psyllids were caught in Morelos, Mexico, in all months from December 1959 to June 1961 except September 1960. The highest catches were in June 1960; the next highest in December 1959 and 1960. It is evident that this psyllid is active throughout most of the year.

Continued studies with the mango seed weevil in Hawaii confirmed previous observations that at least 7 to 8 months are required for adults to become sexually mature. This is roughly the period between normal mango fruiting periods. A few females have been under observation for 17 months without laying eggs. Dissection of individual females and males from this lot showed that the reproductive organs were poorly developed.

B. Insecticidal Control

1. Citrus Insects and Mites. In Florida the most serious pest of citrus is the citrus rust mite. Citrus red mites and Texas citrus mites are also important. In 1961 there were numerous reports of

poor control of rust mites with zineb, one of the most effective of recent materials used by growers. In two groves under observation, control was not satisfactory; in two Valencia blocks postbloom zineb followed by a summer oil-zineb spray gave adequate control. Zineb (75 WP), 1 pound per 100 gallons applied in August 1961 gave satisfactory control of this mite for over 3 months on grapefruit and was superior to Imidan (4 EV) at 1 pint or $\frac{1}{2}$ pint, Sevin (50 WP) 2 pounds and dimethoate (50 EC) 1 pint Hooker Compounds 720 and 16 gave poor control and Niagara 9044 was followed by an increase in rust mites.

Eradex was effective against all three species of mites in Florida but this material was dropped from further development because it produces allergy in workers on repeated exposures. Delnav gave better control of citrus red mites and Texas citrus mites than Trithion or ethion.

Because of the development of mite resistance to new acaricides, there is no generally satisfactory control for the citrus red mite in California where it is now the most serious pest of citrus. The rate of loss of resistance to demeton and ovex in strains collected in 1958 and maintained in the Riverside, Calif., laboratory since then without treatment appeared to be leveling off at a value of 35 to 50 times the tolerance of the non-resistant strain. An accidental exposure to Trithion-treated fruit increased the resistance level of demeton-resistant citrus red mite from 35 to 117 times. Eleven months later the resistance decreased to 11 times. The ovex-resistant strain has had no previous exposure to organic phosphorus compounds. Little or no change occurred in the non-resistant strain. These studies indicate that a significant amount of field-induced resistance may be retained after many generations without exposure to the chemicals.

Chemicals tested as miticides in Florida were also evaluated for toxicity to scale insects. Dimethoate (50 EC) at 1 pint per 100 gallons continued to be the most effective compound. Imidan (4 EV) at 1 or $\frac{1}{2}$ pint was the only other new material with promise. A new formulation of dimethoate EC caused some plant injury when applied with hand sprayers but not when applied with continuous agitation.

In California, growers now have a choice of materials for use in an annual 2-spray program for California red scale control. Dimethoate and parathion alone or in combination at reduced strengths gave excellent control in several comparative tests. Kerosene plus parathion and oil plus malathion were also effective. Shell compound SD 3562 was the most promising of the new materials

screened against California red scale. This material in field sprays did not injure Navel and Valencia oranges. Other compounds screened in the laboratory that compared favorably with parathion were Stauffer compound R 3413, American Cyanamid 43064 and Bayer 45432. California red scales reared from survivors of parathion sprays in 15 generations were only slightly more tolerant of parathion than the untreated strain. Since the difference was about the same as that found after 4 and 8 parathion treatments, no specific resistance was indicated.

Experiments were conducted to obtain further data on possible damage to citrus from application of fruit fly bait sprays following or in combination with copper. There was no injury to fruit when copper, oil, malathion, or Staley's insecticide bait No. 7 (SIB-7) were used separately or in various combinations. SIB-7 applied either alone or in combination with the other materials caused an increase in drop of older leaves.

After a 10-year period in which citrus thrips seldom reached economic levels in southern California, populations increased in the last 2 years to heavy infestations in 1961. Summer infestations were especially difficult to control. The earlier decline in thrips infestations coincided with the general use of parathion for scale control.

2. Subtropical Fruit Flies. In a search in Hawaii for improved bait spray formulations, use of a toxicant in liquid SIB-7 protein hydrolysate without further dilution with water gave promising results. This type of bait spray (with Baytex or malathion technical as the toxicant) may provide means of greatly reducing aerial application costs by decreasing amounts of liquid required per acre. A new 50% wettable powder malathion formulation gave better results than the standard 25% material in preliminary tests, suggesting another possibility for using less water per acre. Cue-lure can be applied directly to foliage with good results in killing male melon flies provided it contains a suitable toxicant. Baytex, 2% was four times as effective as a toxicant in combination with cue-lure as DDVP, 2%, during a 2-week period; kill with Stauffer R-1504, 2%, was 50% greater than with Baytex. Preliminary tests of acid hydrolysate of corn protein in liquid form used in bait sprays with emulsifiable malathion showed that the best formulations were only moderately less efficient than the present standard formulation. Such formulations may have some advantage when aerial applications are made.

In Mexico City, Mexico, screening tests of 33 insecticides in a continuing study to find an insecticide for the Mexican fruit fly with residual toxicity greater than that of malathion and a

comparable low hazard index revealed four that warrant further study in the field. Evaluation of Baytex, a material which has shown unusual promise as a Mexican fruit fly insecticide, has been retarded because it has not been registered for application to edible crops.

The effectiveness of soil applications of emulsifiable, wettable powder and granular formulations of endrin and dieldrin against Mexican fruit fly larvae and pupae in the soil is being studied in Mexico City, Mexico. After two years endrin was superior to dieldrin. Dieldrin was as effective as endrin for 546 days with the exception of the granular formulation. Beginning with the larval introduction made 371 days after application, granular endrin was superior to all other formulations. A waterproofed heptachlor prepared by the Plant Pest Control Division was the most effective of five formulations of this insecticide when tested 218 days after application, slightly more effective after 381 days and about equal to the other after 586 days. At this time both 5 and 10-pound dosages of all formulations gave 50% or less mortality of introduced larvae.

C. Insecticide Residue Determinations

1. Subtropical Fruit Flies. At Mexico City, Mexico, in-package fumigation of grapefruit with ethylene dibromide at 50°, 74°, and 90° F., with dosages of 0.36 ml. and 0.48 ml. per carton for 24 hours, resulted in EDB residues (determined as bromine) 24 hours after treatment ranging from 2 p.p.m. to 8.8 p.p.m. Residues were greatest after treatment at 50° and least when the temperature was 90°.

2. Miscellaneous Crops. Residual bromide resulting from fumigations of asparagus in Hawaii with dosages of 3 to 6 pounds of methyl bromide per 1000 cubic feet for 2 hours at 59° or 70° F. after 3 days storage at 45° F. were almost entirely inorganic bromides and ranged from 48 p.p.m. to 102 p.p.m. Results of cooperative tests at Hoboken, N. J., with Dow Chemical Company indicated that the inorganic bromide residues in Golden Delicious or Lady apples from either methyl bromide alone or in combination with ethylene dibromide at either warm or cool temperatures come very close to or were under the present 5 p.p.m. Food and Drug tolerance. These results differed from those obtained in 1959 when residues were as high as 10 to 20 p.p.m. after warm fumigation and zero after cool fumigation. After consideration of residue analyses in cabbage fumigated with methyl bromide under different conditions, the Food and Drug Administration recently approved a tolerance of 50 p.p.m. inorganic bromide for cabbage. Similar studies are underway with Guar (Cyamopsis) seed.

3. Analytical Equipment.--In further studies at Hoboken, N. J., with the Fumiscope and other thermal conductivity gas analysis equipment used in determining methyl bromide gas concentrations inside fumigation chambers, generally satisfactory readings were obtained under a wide range of temperature conditions. The Fumiscope is small and convenient and appears to be better insulated from outside conditions than other equipment, as well as sufficiently accurate for field use. Study is being continued as to the most desirable procedure for use under high humidity conditions. In further studies with thermal conductivity (T/C) apparatus for checking fumigation gas concentrations, carbon tetrachloride was not promising for use to calibrate T/C sets. Sulfuryl fluoride (Vikane) gave a fast, steady signal and was more promising than carbon tetrachloride. Tests with a special "sachet" for ethylene oxide confirmed the usefulness of the T/C set for checking carboxide fumigations. The T/C equipment has been so sensitive to carboxide that it now appears to be the most useful instrument available for checking carboxide leakage. In further tests this equipment did not appear promising for analysis of ethylene dibromide.

D. Biological Control

1. Citrus Insects and Mites. Laboratory and grove studies to determine the status and value of parasites, predators, and diseases that attack citrus insects and mites, additional natural enemies that may be needed, the effects of pesticides and other grove practices on biological control agents and development of selective treatments and procedures for use in integrated control programs, are long-range objectives of the studies being conducted at Lake Alfred in cooperation with the Florida Citrus Experiment Station and at Orlando, Fla. Sprays containing DDT, copper, captan, nutritional zinc and manganese, Chlorobenzilate, Kelthane, Trithion, and Tedion varied widely in their effects on beneficial species of mites and insects. DDT and Kelthane were most destructive while captan and the nutritional compounds were least harmful to the majority of predators. Fall infestations of Florida red scale were heaviest in DDT and nutritional plots following reduced parasitism by Pseudhomalopoda prima. Heavier chaff scale infestations in DDT, nutritional, and Kelthane plots were correlated with reduced parasitism. Heavier spider mite infestations in DDT and copper plots also suggested an adverse effect of the sprays on natural enemies. Populations of purple scale and its parasite Aphytis lepidosaphes were relatively uniform in all plots. Eradex was toxic to predaceous mites as well as to plant feeding species. It practically eliminated Agistemus mites (predators) and Tydeus mites (fungus feeders) within four weeks after application. Trithion, ethion, and Delnav concentra-

tions at half the usually recommended dosages were much less injurious to beneficial species than Eradex, and Zineb was considerably less so.

A parasite of the snow scale was again recovered at the Orlando station. This species, not abundant in recent years, has been identified as belonging to the Aphytis mytilaspidis group or as being indistinguishable from A. lingnanensis.

Aphytis holoxanthus, a parasite of Florida red scale introduced in the fall of 1960, spread rapidly and was found in practically all of the citrus-producing areas of the State during 1961. Parasitism rates averaged 29% in survey groves in the spring of 1962, with a maximum in one grove of 84%. Parasitism averaged 7% in the spring of 1961.

Periodic scale and scale parasite surveys in 27 Florida groves - 9 untreated, 9 with sulfur in the program, and 9 without sulfur - revealed that scales are most abundant in groves receiving sulfur, and intermediate in abundance in untreated groves. Parasitism of purple and Florida red scales was adversely affected by sulfur but scale populations in all groves were below economic levels. In the third year of comparison of zineb, oil + zineb and sulfur spray programs following postbloom copper and arsenic on grapefruit, scale insects were lowest in the oil-zineb plot and highest in the sulfur. Brevipalpus mites were most numerous in the zineb plot. The predaceous mites, Amblyseius (Typhlodromus) peregrinus and A. quadripilis, again were most abundant in the sulfur plots. Agistemus fleschneri was most numerous in the oil-zineb; Aleurodothrips fasciapennis in the sulfur plot. Sulfur has no effect on this thrips. In two groves in which Manatee or citrus tree snails were excluded from some trees by tanglefoot-copper barriers, no difference in numbers of pest and beneficial species on banded and unbanded trees was evident the second year of the experiment.

Basic research on a new virus disease of the citrus red mite in California, and on possible practical means of storing and utilizing this pathogen have continued to receive major attention by the Riverside station. Two convenient methods of storage of inoculum for six months to a year without loss of virulence were perfected. One method uses storage of the dry bodies of diseased mites at -10° F.; the other, storage of suspension of macerated diseased mites in 3 M glycerine also at -10° F.; the latter showed no loss of virulence after 75 weeks. Activity was lost more quickly at 45° F. Freeze dried preparations also had good keeping qualities, remaining infective after 92 weeks of storage at -10° F.

Sprays of the aqueous suspension of this virus disease of mites caused infection in 100% of the tests where the interval between spraying the host fruit and infesting with mites was 2 hours or less; in 14% with a 24-hour interval; and in none of the tests after 48 hours. The incidence of infection of the citrus red mite by the virus increased with greater population density. Some additives did not prolong the life of the residue but gelatin may have had some effect. The longer life of the natural residues on lemons resulting from the presence of diseased mites has not yet been explained. Fecal deposits removed from such lemons were not infective.

Two predaceous mites, Typhlodromus occidentalis and Phytoseiulus macropilus, were not affected by feeding on diseased red mites.

Earlier reports that a single mite infected with this virus is able to initiate infection in a healthy colony were confirmed. Single inoculated mites introduced into healthy colonies of several hundred mites per lemon induced infection comparable to that produced by spraying them with aqueous suspensions of the pathogen. This virus disease of the citrus red mite has persisted in field plots at Oxnard and Corona, Calif., that were experimentally infected in the fall of 1960. In the Oxnard grove which was heavily infested by mites at the time of treatment, several sub-standard applications of an acaricide were needed to suppress mite populations. In the Corona plots, initially very lightly infested, populations have not built up even though there has been no evidence of high incidence of disease.

Birefringent crystals were found in diseased cultures of the mites but not in healthy colonies. The crystals first appeared 7 to 8 days after inoculation with the virus; they occurred in 84% of the paralyzed and recently dead females and in 59% of the still active mites. The crystals will probably have diagnostic value in laboratory and field studies.

Attempts are underway to establish in Florida the virus disease of citrus red mites which is present in California and also the mite predator, Amblydromella richeri, which is being reared by the Department of Biological Control, University of California, at Riverside.

2. Subtropical Fruit Flies. Infestation data from more than 635,000 fruits collected on Hawaii and Maui since 1945 show that fruit fly infestations in preferred hosts have not changed significantly since 1950. The failure of the present biological

control complex to reduce infestations to levels acceptable in commercial fruit production suggests the desirability of further work on biological control. Parasitization during the year in the Hawaiian Islands exceeded 70% only in fruit flies infesting rose apple, mountain apple, coffee, and Surinam cherry. The average rate in guava was 50%. It was again low in the melon fly and in the Medfly except on these insects in coffee. Parasitization by Opius oophilus was substantially higher in oriental fruit fly pupae than in Medfly pupae when both of these species occurred together in such hosts as loquat, calamondin, cotton, and plum. This parasite again appeared to be much less important as a parasite of the Medfly than of the oriental fruit fly, and might not be able to survive in the complete absence of the latter. No parasites were reared from fruit flies from fruits collected in the Bonin Islands. Although parasite species present in Hawaii, such as O. longicaudatus and O. oophilus, have been reared from fruit collected on Rota, the parasitization rate has rarely exceeded 5%.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Citrus Insects and Mites. Because of resistance to the best of the new acaricides there is no generally satisfactory control available for the citrus red mite in California at the present time, a situation suggesting the need to explore other possible means of control. In exploratory studies at Riverside, with potential chemical sterilants, ENT 24,915, 26,315, and 26,316 reduced productivity of the treated females and viability of eggs and larvae of the second generation; only 1 female among the offspring matured, indicating almost complete sterilization. Fertilized eggs normally produce only females. Male offspring of citrus red mites treated with the chemical sterilant, tepa, were fertile. Normal virgin females mated with such males produced as many females as the checks. These compounds are too toxic for field trials but the results demonstrate effects that may be obtained by contaminating mite environments with them.

The ether extract of carbon which had been used for purification of air in an air-conditioned rearing room was toxic to red mites; the water extract was non-toxic. The ether extract of unused carbon was also nontoxic.

2. Subtropical Fruit Flies. Increased attention was given to the screening and development of information of chemosterilants during the last 15 months in Hawaii. Of about 250 compounds tested on the oriental fruit fly, tepa, tretamine, ENT-22690

and ENT-32838 showed promise as both male and female chemosterilants, ENT-22878, 4878, 23562, and 23569 showed possible value as male sterilants, and ENT-15239, 50170, and D-57 showed value as female sterilants. In tests with a wide range of dosages most materials were more effective on the oriental fruit fly and the melon fly than on the Mediterranean fruit fly. Effective sterilization by tepa, apholate, and tretamine was obtained at dosages of .0004 to .0125% in drinking water and when adults were anesthetized and dipped for 15 seconds in .016 to .25% solutions. When apholate was included in the carrot-rearing media at 2%, no sterilization resulted and mortality of larvae and pupae was high. High mortality also resulted at dosages as low as .5% when mature larvae were dipped in solutions for 15 seconds. Dosages in dips or drinking water that gave sterilization were generally non-injurious except in some melon fly tests. Pupal dips at concentrations up to .5% had no significant effect on eggs or fertility of the melon fly.

More than 1600 possible fruit fly development or reproduction inhibitors have been screened in Mexico City since 1959 at low concentration in fruit fly diets or in drinking water. Thirty-two materials proved to be highly effective, affecting testes, ovaries or gonads of both sexes. Flies fed biotin or vitamin H produced no eggs and male mortality was abnormal. Adult flies were permanently sterilized when immersed for 5 seconds in a 0.2% aqueous solution of tepa and also when the material was applied in an atomized spray. Tepa in the larval rearing medium was ineffective. Immersion of puparia in a 5% tepa solution followed by drying was ineffective but when the puparia were immersed for one minute and then held without drying, complete sterility resulted. Pre-emergence and post-emergence mortalities of flies from immersed puparia were normal. When sterile and normal flies were crossed, the normal females mated with sterile males laid 6,915 eggs with less than 1% hatch. There was no larval development. Treated females mated with normal males laid no eggs. Sterile females mated with sterile males laid 4 eggs but none of these hatched. In a series of observations on mating behavior in which aggressiveness of males from puparia treated with 5% tepa solution was compared with males from untreated puparia, ratios of sterile males mating to untreated males mating were 1.14:1 at 12 - 29 days of age and 1.16:1 at 33 - 50 days. When puparia treated with 5% tepa solution were released in a semi-isolated 10-acre mango grove in Mexico bearing a light, though heavily infested off-season crop of fruit and a heavy set of immature fruit, infestation was greatly reduced and a major part of the regular season crop was protected and harvested, whereas virtually all fruit in check groves was lost from infestation.

After treatment of 12-day old pupae of the Mexican fruit fly with 5,000 r of radiation from cobalt 60, emerging adults were sterile. In a former study treatment of puparia was more effective at 90 r per minute than at 10 r at a marginal sterilization dosage of 2,000 r. In recent tests after sterilization of puparia at rates of 2,695 r and 42.8 r per minute there was no apparent effect of the higher dosage rate on emergence or longevity of adults. Both sexes were sterilized when a 5000 r dosage was fractioned, with application of 2,500 r being followed by the same amount after a 24-hour interval. When 12-day-old puparia were administered dosages up to 7,000 r in an N₂ atmosphere, there was little sterilization effect; when puparia were irradiated in an O₂ atmosphere at 7,000 r some fertile eggs were obtained from emerged adults.

The release of sterile flies was continued in 1961 at the same two locations in Mexico where sterile flies were released in 1960. At Santa Rosa, where 838,000 sterile flies were released in a semi-isolated hacienda with about one acre of citrus (mostly grapefruit) and one square mile of other hosts, only 5.5 larvae per pound were recovered from 2 tons of fruit despite an infestation potentially double that of the preceding year. In the previous season, after release of 1,172,000 sterile flies, infestations averaged 6.9 per pound. At San Carlos similar results were obtained in 1960 and 1961. Releases made at San Carlos in February 1962 and continued until June 6 gave a mean 8:1 ratio of non-gravid to gravid flies but the native fly population was so high that there was little suppression of infestation.

In a male annihilation test in the Bonin Islands (approximately 27 square miles of land mass) initiated late in 1960 and continued until the present time, Celotex wafers (2 $\frac{1}{4}$ " x 2 $\frac{1}{4}$ " x 5/16"), saturated with methyl eugenol containing 3% by volume of dibrom, which attract and kill male oriental fruit flies, have been distributed by air at the rate of 70 per square mile. Intervals between applications ranged from 10 to 67 days. Permanent poisoned-bait stations serviced from the ground were maintained in an inhabited area. Trap catches averaged 47,400 oriental fruit fly males per 1000 trap days in March, 1958, and 13,700 in January 1960 before treatments began. Catches were only 170 flies per 1000 trap days in March 1961 and 194 in March, 114 in April, 204 in May, and 81 in June 1962. The lowest density during the experiment of 28 flies per 1000 trap days was attained in September 1961. For the first time in several years, no infestations appeared in recent harvested tomatoes in the Islands but after sampling was discontinued there was a rather heavy attack in scattered tomatoes left in the field at the end of the crop season. Increases in flies during periods when unusually

long intervals between applications were necessary, reflected the high reproductive potential of the oriental fruit fly and need for continued regular suppression of males for several weeks beyond the last fly catches if this method is to achieve eradication.

Field tests of the sterile-male release method were started in late 1960 on Rota, a small island located 40 miles northeast of Guam. The oriental fruit fly and the melon fly were released until June 1961, when work with the melon fly was discontinued because of inability to give attention to both species simultaneously. In the continuing studies with the oriental fruit fly a wealth of information with much basic significance has been accumulated. Thus far, however, sustained overflooding of the wild fly population with sterile flies at the 10:1 ratio or higher, estimated to be required for effectiveness, has not been achieved. Late in November 1961 the release rate was increased to almost 10 million pupae per week, with ground emergences supplementing aerial drops, and overflooding was attained in all areas with a ratio as high as 5 sterile flies to 1 wild fly in some areas and an average of at least 4 to 1 on the southwest half of the island where preferred hosts are most abundant. An estimated one-fourth billion sterile oriental fruit flies were released during a recent 12-month period. The mid-February 1962 release rate was 20 times as high as the estimated weekly birth rate. Declining wildfly birth rates and seasonably low populations are the basis for hope that effective overflooding may yet be obtained.

Fruit flies from ground releases distributed themselves satisfactorily throughout most areas, and their survival and longevity may be better than that of flies released from aircraft. Some of the flies dropped from airplanes too close to the shoreline of the small island drifted out to sea, particularly when boxes broke open at plane height. Chutes designed to deliver boxes into the airstream with less shock were tested but in the best performance from 18 to 20% were ripped open by the air blast. Throwing the boxes out by hand at a higher level through the open door of the airplane eliminated most breakup and this method is now being used.

The southwestern end of Rota has consistently produced the most flies, partly because of immigration from the upwind (NE) end, but mainly because of the greater abundance of hosts there throughout the season. The weekly mean percentages of sterile flies in the southwest (downwind) areas was 93 in early March 1962, 67 in early April, and 89 in early May. Thereafter, by the end of June, there was a marked decline to 35%, because of increases in the number of

wild flies. In early March 1962, the wild fly per-trap-day catch in the northeastern upwind portion of the island increased from 75% sterile in early March to 98.5% by early June and wild fly catches were only 0.2 per trap day. By the end of June there was still a 12:1 sterile-wild fly ratio in this part of the island. Migration from high-producing areas has since resulted in an increase in wild flies.

Supplies and equipment are being assembled for resumption of sterile melon fly tests on Rota. This species reproduces largely in cultivated farm plots. Bait sprays are being applied to the producing areas (50 to 100 acres) to reduce the numbers of flies to a point where they may be eliminated with releases of sterile flies at a minimum cost.

Attempts to segregate and produce a genetically-marked melon fly strain have failed. Rare specimens of wild flies with very faint wing markings or with white instead of yellow markings have been found in the field on Rota. Flies so marked could be used as indicators of sterility if a laboratory strain with these characteristics could be produced. Attempts to inter-breed the marked wild flies to produce a pure strain have not been successful in tests now in the third generation. All production, except 3 individuals, reverted to the normal markings.

In Hawaii 220 fermentation products furnished by the Northern Utilization and Development Division were tested against standard yeast hydrolysate type M liquid lure in laboratory olfactometer tests. Forty-three were attractive to one species of fruit fly only and 45 were attractive to two species. Fifteen were equal or superior to the standard in attractiveness to all three fruit flies. Field tests with the last, and materials that were especially attractive to the melon fly or the Medfly, are desirable. Screening of fermentation products was discontinued in December since none had approached the outstanding effectiveness of the best synthetic male attractants. Two hundred fifteen candidate chemical lures, supplied largely by the Pesticide Chemicals Research Branch, were also tested. Only two were highly attractive to the male Medfly in trap tests but in wick tests these were much less attractive than standard trimedlure. None of the others were attractive enough to warrant field evaluation. Promising enzymatic protein hydrolysates of soybean and cottonseed were attractive to all three species of fruit flies in Hawaii, particularly female melon flies. The addition of borax, a development of the Mexico laboratory, resulted in increased catches of some flies but not others when used with either one or the other of these hydrolysates.

The long-lasting quality of cue-lure as a melon fly male attractant was demonstrated in a field test in which cotton wicks, originally treated 6 months previously with 2 ml. of lure containing 1% dibrom, were no less effective in attracting melon flies than fresh-treated wicks. A comparison of crude and distilled samples of cue-lure during a half-year period showed that purified materials were only 15% better than the crude material. Cue-lure in combination with 1% dibrom did not crystallize in Hawaii but when used on Rota at higher temperatures, crystallization occurred. With periodic addition of more lure the wicks accumulated up to 1.5 times the original concentration in crystalline form.

In olfactometer tests recrystallized solid fractions (MP 72 - 73° C.) from trimedlure had little or no attraction for the Medfly, while a purified solid sample with a melting point of 57 - 58° C. proved very attractive both initially and residually. At least, two solid isomers may be present in trimedlure - one definitely more attractive than the other. This may account for the variability observed in field tests of different lots of trimedlure when crystallization occurred. In the early tests, crystallized material remained as effective as the liquid but more recently the crystalline form has lost practically all attraction after 6 to 7 weeks' exposure in the field. A field test of the solid and liquid fractions of trimedlure separated from the same production lot confirmed the laboratory results.

Celotex wafers treated with methyl eugenol plus 3% dibrom and then exposed on the soil for three months in sunny and shaded areas in the Bonin Islands retained approximately 55% of the effectiveness of freshly treated wafers. Those exposed for 5 months in the sun were still 17% as effective as fresh wafers. The efficiency of treated wafers stored for 12 weeks in the aluminum canisters used when making lure drops was not affected.

When methyl eugenol, cue-lure, and trimedlure were combined in the same trap there was no reduction in catches of melon fly but a significant reduction in catches of oriental fruit flies and Medflies. When one species was unusually scarce the lure for that species had less of a depressive effect on the other catches than when the species was abundant. In other tests the presence of methyl eugenol may have added to, but rarely detracted from, the attractiveness of cue-lure to the melon fly. Cue-lure greatly depressed the attractiveness of methyl eugenol to the oriental fruit fly. Trimedlure had a much less suppressive effect on the performance of cue-lure than on methyl eugenol. Medfly catches

may be inhibited slightly by the presence of cue-lure and the catches of this species are depressed even more by the presence of methyl eugenol. Despite the depression in trimedlure efficiency resulting from its use in multiple lure traps, it was as effective in such traps as the most attractive angelica seed oil used alone. As previously reported, the most efficient method of utilizing the three lures is together in the same trap rather than in three separate traps.

An important need is a more effective lure for the Mexican fruit fly, especially one that will be effective when used in a dry trap. The 1,369 coded compounds supplied during the year by the Pesticide Chemicals Research Branch made a total of 5,384 ENT compounds which have been tested in the lure screening program thus far, in addition to more than 510 fermentation products, including 360 supplied by the Northern Utilization Research and Development Division in 1961. Of all these materials one fermentation product in combination with 8% light brown sugar showed considerable attractiveness in recent tests and will be tested further.

Enzymatic hydrolysates of meat, soybean, and cottonseed gave promising results in the olfactometer, with the cottonseed material ENT-44,014-X being most attractive. In mango orchards, cottonseed hydrolysate was also most effective, giving catches at seven locations during 53 trap-weeks 1.46 times as large as those obtained with the standard Staley's protein insecticide bait No. 7 (SIB-7). The latter is an acid hydrolysate of corn protein mixed with corn steep liquor. Like other proteins cottonseed hydrolysate putrefies, causing discoloration of trap liquids and disintegration of soft-bodied insects such as fruit flies. Addition of borax at the 2% level eliminated these difficulties, and increased catches by 12%. SIB-7 with borax is now being used in all traps in the fruit fly detection program in California.

An attractive fermentation product, ENT-191 F W.C., added to SIB-7 at 1% increased the catch to 2.51 times that of SIB-7 alone.

Among 112 miscellaneous products tested in the field, Bovril, a beef consomme containing hydrolyzed beef protein and yeast extract among other components, was most attractive, but none of the ingredients of Bovril either alone or in combination caught as many flies as the original material.

Dry traps have not been effective when baited with currently available Mexican fruit fly lures. When traps containing ammonium hydroxide on wicks suspended over liquids were maintained at 60

and 30% R.H., catches were reduced sufficiently to suggest that relative humidity may be a factor in the attractiveness of Mexican fruit fly lures. Chlordane-lindane and methoxychlor-BHC-toxaphene-malathion mixtures suspended in small cloth bags in invaginated traps baited with standard lures, reduced catches from 34 to 89%.

The invaginated plastic trap reported on in 1960 continued to be most effective of twenty-two designs tested in 1961.

3. Miscellaneous Insect Pests of Subtropical Fruits. Mango seed weevils exposed to 10,000 r and above of gamma radiation in Hawaii died within 8 months and failed to lay eggs. There may be some recovery at 7500 r. No eggs were laid by weevils irradiated at 7500 or 50,000 r. Common mangoes stored in a tightly closed plastic bag at 32 - 36° F. remained firm and sound for 90 days. This assures a continuing supply of fruit in the off-season for use in mango weevil tests.

F. Evaluation of Equipment for Insect Detection and Control

1. Citrus Insects and Mites. In Florida, aerial applications of toxaphene dusts and emulsifiable concentrates were effective in controlling the citrus rust mite, being particularly effective against the active stages.

2. Subtropical Fruit Flies. Vaporization of ethylene dibromide (EDB) with an electric stove is a common practice in commercial fumigations, but this procedure causes corrosion of heaters and connections and may be responsible for operational failures. A gravity flow method for applying ethylene dibromide, developed in Mexico City in cooperation with the Plant Pest Control Division, in which the liquid fumigant is volatilized by introducing it into a high velocity squirrel cage fan, was as effective as vaporization with heat.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. Ten of 32 compounds tested in the fumigant-screening program in Hawaii were selected for further testing. Five were effective against both eggs and larvae and 5 principally against larvae. Amyl iodide and 1,2-dibromo-propane gave good results when tested in aqueous dips. None of the materials tested approached ethylene dibromide or ethylene chlorobromide in effectiveness.

Increasing the oxygen content of air to 75% or over during fumigation increased the effectiveness of methyl bromide against naked fruit fly eggs. This furnishes an important lead in the search for methods to improve fumigation techniques and decrease phytotoxicity.

A 5-minute aqueous dip of EDB at 1058 mg./l. at 80° F. was completely effective against oriental fruit fly in papaya. This short period treatment promises to be an extremely useful quarantine treatment. Papayas were not injured by effective dosages. Since heat was not involved, the dip failed to retard development of storage rots in papaya, but it may be used advantageously for other fruits with good keeping qualities. Harven or DHA-S, antimicrobial agents from the Dow Chemical Company, increased the shelf life of papayas since they remained firmer and less moldy after 5-minute treatments at concentrations of 2 or 4% actual ingredient in aqueous solutions. These materials could be incorporated in aqueous dips of EDB or ethylene chlorobromide for 5-minute treatments at 80° F.

Five-minute and 20-minute dip treatments at 115° F. with ethylene chlorobromide were determined for use as alternate treatments for ethylene dibromide. Dosage-mortality curves calculated from 126 tests with over 6,000 papayas infested with nearly 700,000 oriental fruit fly eggs and larvae, indicated that 222.4 mg./l. for the 20-minute dip and 744 mg./l. for the 5-minute dip will give complete kill of fruit flies. These treatments were also non-injurious to papayas.

Williams hybrid banana, a Cavendish mutant introduced from Australia, was very tolerant to fumigation with EDB at a dosage of 0.5 pound per 1000 cubic feet for 2 hours at 70° F. Fruits were severely injured when fumigated with methyl bromide at 2 pounds per 1000 cubic feet for 3 hours.

The favorable response of a number of local Hawaiian avocado varieties to fumigation with methyl bromide and the effectiveness of this treatment against fruit flies indicates promise of this material for quarantine use at a dosage of 2 pounds per 1000 cubic feet for 4 hours at 70° F. The varieties Kahaluu and Kashi-lan were uninjured by treatment. Linda, Tumin, Haas, and two seedlings showed superficial skin blemishes which were masked by a normal purple color upon ripening. The varieties Beardslee and Zutano showed moderate skin scald but no internal damage or effect on taste. The treatment cannot be used on Fuerte, Rincon, and Bacon varieties which ripened unevenly, developed browning of tissue surrounding the seed cavity, or decayed rapidly because of severe skin injury.

Two vertical or horizontal slits 1/8", 3/32", or 1/4" wide by 2" long on each of 4 sides of cartons containing fumigated papayas permitted entry of fruit flies and reinfestation when the cartons were exposed to infestation.

Fumigation of oranges packed in standard orange cartons at 50° F. with EDB would require at least 24 ounces/1000 cubic feet for 2 hours according to mortality data obtained with medfly infested papayas similarly packed at time of fumigation. EDB residues in Hawaiian navel oranges were 11.1 and 2.9 p.p.m., one and three days after fumigation when stored at room temperatures of 77 - 85° F. Inorganic bromides increased to 5.4 p.p.m. in 4 days. Results were similar to those for prepacked papayas fumigated with the standard dosage at 70° F.

Ethylene chlorobromide is more promising than EDB for fumigation of sweet peppers of the Yolo Wonder variety infested with melon, oriental, and Mediterranean fruit flies. The estimated dosage at probit 9 is 19 ounces/1000 cubic feet for 2 hours at 70° F. for EDB. Sixty-seven to 75% of the peppers so treated became unmarketable after 5 days. Though tests were few, there was indication that a lower dosage could be used with ethylene chlorobromide and that the tolerance to this fumigant would be higher.

In tests continued on summer squash (Bush scallop), a dosage of approximately 6 ounces/1000 cubic feet for 2 hours at 70° F. was necessary to destroy infestations of melon, oriental, and Mediterranean fruit flies. More data are needed to recommend application of the standard treatment developed for zucchini squash to this commodity.

Most of the work on ethylene dibromide in Mexico in 1961 had as its object the development of procedures and schedules better suited for use in emergency situations than those now available. Possibilities for short period ethylene dibromide fumigation were explored in tests involving treatment of 2.5 tons of grapefruit containing 8,400 larvae and nearly 1 ton of mangoes containing 75,000 eggs and larvae. After exposures for 15 minutes at temperatures of 65° to 72° F., there were 4 and 3 survivors at the 24- and 32-ounce grapefruit dosages, and 7 and 1 survivors at the 16- and 24-ounce mango dosages. Since amounts of fumigant used were much higher than those ordinarily employed in 2-hour fumigations, no effort was made to obtain tolerance and residue data.

Short period fumigation, consisting of introduction of vaporized ethylene dibromide into fumigation chambers under 2 to 8 inches of vacuum followed by immediate removal of fruit, was evaluated

at dosages of 4 to 32 ounces per 1000 cubic feet, both with and without circulation. Adequate kill of the Mexican fruit fly was not obtained in mangoes even at the highest dosage. After fumigation of mangoes containing 59,800 eggs and larvae under a polyethylene (6 mil) tarpaulin, there were 3 survivors at 8 ounces, 2 at 12 ounces, and none at 32 ounces per 1000 cubic feet. A blower provided circulation and the floor was unpainted smooth cement. Other tarpaulin fumigations with ethylene dibromide suggested that about 20 ounces would be required for security kill. Before EDB fumigation under tarpaulins can be considered as a method for treating loaded trucks, sorption by the truck body or trailer and possible effects of lubricants on fumigants will need to be evaluated.

Dosage-mortality data on an in-package treatment of fruit with EDB were previously obtained at 74° F. In recent tests with grapefruit at 50°, 74°, and 90° F. with dosages of 0.36 ml. and 0.48 ml. per carton for 24 hours, mortalities were approximately 99% or better regardless of temperature or dosage.

The investigation of ionizing radiation as a possible substitute for fumigation, heat, or cold treatments to disinsectize fruits, vegetables, and baggage has been promising enough to justify continued attention. Pending development of equipment to permit application on a quasi-commercial scale, work on this project in Honolulu, Hawaii, has been limited to a few infested host and tolerance tests. Tomato varieties Anahu, Step 346, and N-51 tolerated 25,000 and 50,000 r of gamma radiation. The tomatoes turned soft after exposure to 100,000 r. Green fruits were more tolerant than ripe fruits. Only the sound fruits stored well after irradiation. Williams hybrid bananas were scalded when exposed to from 10,000 to 50,000 r of gamma radiation, but ripened well and were palatable after storage at room temperature. Treatment accelerated ripening. Fully colored Haden and Pirie mangoes showed no injury when exposed to 100,000 r. Mature green fruits tolerated no more than 15,000 r, and one-quarter ripe and one-half ripe fruits tolerated 25,000 to 50,000 r with little or no ill effects except accelerated ripening. Ten fruit fly parasites, Opius oophilus and O. longicaudatus, were more resistant to gamma radiation than either the Mediterranean fruit fly or the oriental fruit fly. Tests conducted with field-infested yellow and strawberry guava, ball kamani, false kamani, hog plum, and Terminalia chebula showed that 5.4% of the parasites exposed to 8,000 r emerged as adults. Only 0.1% of oriental fruit flies and Medflies developed to the adult stage. An exposure of 10,000 r prevented emergence of flies or parasites.

When gamma radiation was applied to mature laboratory-reared Mexican fruit fly larvae for varying periods at the rate of 136 r per minute, radiation of 5,400 larvae indicated that probit 9 security for naked larvae would require a dosage of approximately 1,900 r. When infested mangoes were treated with radiation from cobalt 60 at dosages ranging from 500 r to 5,000 r at the rate of 1,500 r per minute, no oviposition was recorded from flies surviving the 1,000 r dose. Only 1 malformed male survived at each of the 2,000 r and 2,500 r treatments and there were no recoveries at 3,000 r or above.

2. Deciduous Fruit Insects. Further progress was made at Hoboken, N. J., in the development of a fumigation treatment for plum curculio in apples and other fruits needed as a condition for movement of these fresh fruits to west coast markets. In small-scale tests, methyl bromide, 2 pounds alone, or $1\frac{1}{2}$ pounds in combination with $\frac{1}{2}$ pound of ethylene dibromide, again gave complete kill of plum curculio larvae infesting mature Jonathan apples when exposures were $1\frac{3}{4}$ hour near 72° F. or $3\frac{1}{2}$ or 3 hours respectively, near 53° F. under load. Complete kill was obtained of apple maggot larvae and eggs, confirming previous results. Good efficiency against plum curculio in infested mature plums was again indicated. Methyl bromide-ethylene dibromide mixture was more effective against plum curculio than methyl bromide alone at temperatures near 41° F. These results were similar to previous findings at temperatures near 52° F. At temperatures between 32° and 39° F., the adults exhibited high resistance to methyl bromide with survivors occurring after exposure to 3 pounds per 1000 cubic feet for 5 hours or less. Progress was also made in the development of a fumigation treatment for eastern blueberries infested with plum curculio or blueberry maggot. Ethylene dibromide alone in either warm or cool fumigations (without load) was somewhat more effective than methyl bromide alone. The combination of $\frac{1}{2}$ pound of ethylene dibromide with $1\frac{1}{2}$ pounds of methyl bromide had its usual high efficiency against larvae. Older pupae continued to survive various schedules in both apples and blueberries. Cranberry fruitworm larvae in blueberries were quite susceptible to methyl bromide, low schedules giving complete kill.

The tolerance of Chilean and other fruits to methyl bromide fumigation at cold temperatures near 40° F. (a treatment in wide, practical use since 1954) was reviewed. Previous tests at Hoboken had shown that Chilean plums, South African grapes and apricots, U. S. peaches, plums, grapes, and green pears have good tolerance, and results with several commercial varieties of apples, including Red and Golden Delicious, were also satisfactory. Mature pears were severely injured, and the tolerance of MacIntosh apples

was questionable. In 1961 two varieties of Chilean grapes (Almeria and Emperor) demonstrated good tolerance to methyl bromide.

3. Miscellaneous Crops. In fumigation tests in Hawaii, New Zealand asparagus tolerated up to 6 pounds of methyl bromide per 1000 cubic feet for 2 hours at 59° or 70° F. without injury or effect on flavor. The dosage of 8 pounds at 59° caused the asparagus to turn dark green when cooked and flavor was altered. Fumigation is required to guard against introduction of a New Zealand mite. The bean butterfly, Lampides boeticus, in Crotolaria sp., and the bean pod borer, Marcus testulalis, in green beans were killed by fumigation with methyl bromide at a dosage of 0.5 pound per 1000 cubic feet for 2 hours at 70° F. in tests conducted in Honolulu for the Plant Quarantine Division.

Evergreen tree seeds, including Scotch, mugho and Australian pine, demonstrated good tolerance to methyl bromide fumigation in 1961. The seeds were set for germination two to six weeks after treatment. In 1960 some injury was noted after 8 months of warm storage in Geneva, N. Y.

Cabbage from New York showed good tolerance to methyl bromide at dosages up to 5 pounds per 1000 cubic feet for 3 hours, NAP, or 3 pounds for 2 hours under 15 inches vacuum at temperatures near 51° F. Slight injury evidenced by necrotic spots near the mid-ribs of the inner leaves occurred after a 6-pound, 5-hour, NAP, 42° schedule. These and earlier tests on cabbage from Israel gave substantial evidence of the safety of the present treatment.

In further small-scale tests, at the New Jersey port of entry, with gall midge larvae, Phytophaga sp., intercepted by the Plant Quarantine Division in imported spruce seed, HCN fumigation again showed promise. These larvae had previously been resistant to methyl bromide - possibly due to a diapause condition. Carbon tetrachloride (a saturated atmosphere containing about 58 pounds per 1000 cubic feet near 75° F.) and dry heat (10 minutes at approximately 130° - 132° F.) also had good efficiency. Acritet (34% acrylonitrile and 66% carbon tetrachloride) at 4 pounds for 10 hours under high sustained vacuum with load, permitted some survival.

Tests in New Jersey and Maryland indicated that two varieties of narcissus bulbs (Tunis and First) had good tolerance to methyl bromide even when fumigated approximately five months after harvest. Small-scale forcing tests of the bulbs showed no injury to the flowers or leaves by the treatment for bulb scale mite after 2½ hours of fumigations at 65° with up to 4 pounds of methyl

bromide at NAP, high sustained vacuum, or vacuum reduced to NAP after $\frac{1}{2}$ hour or after two NAP fumigations made at a 2-week interval. At Beltsville in fumigated bulbs held for forcing, complete control of the bulb scale mite was attained except at the 2-pound NAP dosage. Bulbs held at Hoboken for approximately three months showed extremely high mite mortality but in some cases some mite eggs appeared to have survived. These variable results are similar to some previous findings. Preliminary tests with methallyl chloride, HCN, carboxide or methyl acetate showed little promise for practical use at near or beyond the bulb tolerance limits.

4. Snails. In recognition of continuing needs of the Armed Forces and Plant Quarantine Division, further work was done at Hoboken, N. J., on quarantine treatments for estivated Cochlicella and Theba snails intercepted on military and other cargo from Mediterranean areas. Substantial numbers survived over eight months of very dry storage without food or water. A mixture of ethylene oxide 10% and carbon dioxide 90% (carboxide) continued to show good efficiency at warm and cool temperatures. Carboxide was recommended at $22\frac{1}{2}$ pounds per 1000 cubic feet for 72 hours at 70° F. or above, and $27\frac{1}{2}$ pounds at 55° - 69° F. for large scale trials under direction of the U. S. Armed Forces Pest Control Board. Further tests with sulfuryl fluoride (Vikane) confirmed its efficiency as a snail fumigant at warm temperatures but this material failed repeatedly at cool temperatures near 55°. HCN again showed good efficiency and high vacuum fumigation schedules of $2\frac{1}{2}$ pounds for 6 hours for Theba pisana and 16 hours for Cochlicella were suggested for emergency use. Methyl bromide continued to show good efficiency against snails at cool temperatures. Tentative schedules have been recommended. Fumigation resistance noted in 1961 in naturally estivated snails was similar to that for 1960 snails. Estivated snails were again found to be more resistant than reactivated snails. Carbon tetrachloride at high dosages showed good efficiency as a treatment. A new Cochlicella snail, C. conoidea, intercepted in test shipments was about as resistant as C. barbara in preliminary tests.

In New Jersey tests, carbon tetrachloride at natural atmospheric pressure, and HCN and acrylonitrile under high vacuum, showed some promise for control of small, juvenile snails, Helicella sp., intercepted in Rosmarinus seed shipments. The problem presented by this snail is complicated by the fact that any suitable treatment must also be tolerated by the seeds. Methyl bromide fumigation at the usual seed schedule was not completely effective. Carbon tetrachloride at saturated concentrations in the atmosphere (near 58 pounds per 1000 cubic feet) with a 16-hour overnight exposure, has long been an alternate treatment for small

lots of infested seeds but little if any information on its effect on seed germination has been available. In recent tests, white clover, alfalfa and kudzu-vine seeds tolerated carbon tetrachloride even after a 72-hour fumigation period. In the case of clover seed, germination was good after seven months' storage. The carbon tetrachloride treatment may not be tolerated so well by other plant materials since a 16-hour fumigation in an atmosphere saturated with this material killed rhizomes of A. ulvaceus, an aquatic plant.

5. Fumigation Facilities. Tests at Hoboken, N. J., indicated that two coats of either ordinary shellac or an aluminum paint (either asphalt or linseed oil base) will reduce methyl bromide sorption loss on raw wood. Two brands of spar varnish and a rubber-base, latex paint were less effective. Three tests of wood samples painted nearly four years previously with one coat of two types of epoxy paints (Senox and Devran) or two coats of phenolic liner varnish or oil base enamel again gave good results.

Unpainted wood sorbed substantial amounts of methyl bromide each time more gas was added to the fumigation chamber in tests at Hoboken, N. J. The additions of gas are often required to maintain minimum gas concentrations. Sand, vermiculite, and perlite, which are now being used as plant packing materials, seemed to sorb little methyl bromide and gas penetration into them was generally good. Indications are these materials will not interfere with methyl bromide fumigation.

H. Varietal Evaluation for Insect Resistance

1. Subtropical Fruit Flies. Three varieties of avocados (Bacon, Fuerte, and Zutano) grown in California and then shipped to Hawaii were susceptible to oriental fruit fly infestation when exposed to 5,000, 15,000 or 100,000 caged flies for periods of $2\frac{1}{2}$ to 16 hours.

I. Insect Vectors of Diseases

1. Citrus. Emphasis is continuing at Orlando, Fla., on studies of factors influencing spread of the tristeza virus by aphids. Low transmission efficiency makes it difficult to draw conclusions. Experiments thus far have failed to substantiate indicated differences between the vector efficiency and sources of virus inoculum but there is increasing evidence of a difference in efficiency among colonies of the melon aphid as vectors.

Melon aphids transmitted the virus from citrus thorns. Negative results in tests with spirea aphids confirmed earlier indications

that this aphid is an inefficient vector of tristeza. In additional tests, neither the citrus whitefly nor the green peach aphid transmitted tristeza. Two species of sharpshooters are considered possible vectors of citrus blight. Disposable traps caught equal numbers of both species in the spring but Homalodisca coagulata outnumbered Oncometopia undata by about 10 to 1 in the fall. Catches were low in the summer. Methods of rearing these species for vector tests are underway.

The citrus whitefly and green peach aphid did not transmit tristeza virus in a limited number of additional tests. Experiments with the citrus red mite are awaiting possible symptom development. Other vector tests initiated during the year included xyloporosis transmission with spirea aphids, exocortis transmission with spirea aphids and a leafhopper, Homalodisca coagulata, and citrus blight transmission with this same leafhopper and citrus mealybugs. No symptoms of xyloporosis, exocortis, or citrus blight have developed in previous experiments involving these viruses, all of which have unusually long incubation periods.

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CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT
Agricultural Engineering Research Division, ARS

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, only recently initiated, has already resulted in sizeable cost reductions, but the potential savings for these crops and vegetables are enormous.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is currently restricted to a survey of citrus research needs and feasibility.

The Federal engineering effort devoted to research in this area is 28.4 professional man-years of which .4 is devoted to citrus.

RELATED PROGRAM OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 48.8 professional man-years involved on all commodities, of which 2.4 were devoted to citrus in the Southern and Western regions.

Industry and other organizations conduct engineering research on equipment and methods for the harvesting of crops. Both full line and small manufacturers cooperate in USDA research through loan of equipment. Farm operators and organizations furnish land, equipment, and facilities for evaluation of experimental harvesting equipment. Much of the industrial experimental development of harvesting equipment is highly confidential and is generally not made available to public researchers.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

In response to a request by Congress, a study was made of the feasibility of special engineering research on mechanical aids in the harvesting of citrus crops. To carry on this study, an engineer was detailed to Florida for four months during the 1961-62 harvesting season. Another engineer spent approximately one month studying citrus production in the California area. Visits were also made to Arizona and Texas to study problems in those areas. The report of the study, as submitted to Congress, included an analysis of the current state of citrus mechanization, results of preliminary USDA research, and a suggested future USDA research program.

During this preliminary study period, several tree and limb shaking devices were made available for testing by the USDA at the Citrus Experiment Station, Lake Alfred, Fla. While time did not permit investigation of the performance and efficiency of machines with wide ranges of amplitudes and frequencies, fruit removal of 50 to 70 percent was achieved using strokes of 1- to 1 1/2-inches. It is probable that the proper combination of frequency and strokes will remove over 90 percent of the fruit. The USDA engineer also assisted Experiment Station workers in a study of the use of an oscillating air blast as a fruit removal method. Using oscillating blasts with velocities up to 125 m.p.h., 99 percent separation of grapefruit was achieved in the tests. Considerable leaf damage resulted, however. The effect of damage to the tree and to the fruit with either this method or by the shaking method while currently unknown, will be determined in future trials.

II. UTILIZATION RESEARCH AND DEVELOPMENT

PROCESSING AND PRODUCTS

Southern Utilization Research and Development Div., ARS

Problem. The citrus and subtropical fruit production of the Southern Region is an expanding industry with the need for the development of better, as well as new-type consumer products, and for the improvement of present or invention of new processing procedures and machinery. These advances are required to regularly utilize the currently large production, particularly of oranges and grapefruit, and the anticipated higher production of these fruits, to the economic advantage of the growers and consumers. Basic research is needed to lay the groundwork for these advances. This research is needed, for example, on the composition and physical nature of essential oils, flavonoids, including bitter constituents, constituents responsible for oxidized off-flavors, carotenoids, and the like, which determine many of the sensory characteristics, and which affect product quality and stability. Other problems whose solutions are dependent upon the availability of more detailed compositional and physical data are: cloud stability, gelation, discoloration, fermentation, and the like. Increased production of citrus has stimulated the development of new products but many of these are urgently in need of improvement which will depend in part upon advances in basic research. New products are needed to attract new markets and also to reduce packaging and shipping costs. Research is needed to improve frozen citrus concentrates as processing procedures change, to develop better high density concentrate products, citrus powders, chilled juice and section products, pulp-fortified products, and to develop new or improved canned products which have a natural fruit flavor. Along with progress on product development there is a serious need to improve the actual processing procedures, processing equipment, and packaging operations and materials, to obtain and maintain the most desirable fruit characteristics. As an illustration, research is needed to develop less expensive dehydration equipment and an improved process for the production of citrus powders.

USDA PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, bacteriologists, food technologists, and a chemical engineer engaged in both basic and applied utilization research studies on citrus and subtropical fruits of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on chemical composition and physical properties of citrus and subtropical fruits, and their products and byproducts is conducted at the U. S. Fruit and Vegetable Products Laboratories at Weslaco, Texas and Winter Haven, Florida. This information provides the necessary basis for efficient research in developing new and improved food products and processing technology. At the Weslaco Laboratory the program includes investigations of the origin of carotenoid precursors and the biochemical mechanisms of their conversion to carotenoids in grapefruit as a basis for improvement of processing characteristics of and products from colored grapefruit. The Texas Agricultural Experiment Station (substation 15, Weslaco), Citrus Rootstock Investigations Laboratory (CR,ARS, Weslaco), and the Texas College of Arts and Industries are providing grapefruit of known history and conducting, or cooperating in conducting, on the tree tests. At the Winter Haven Laboratory the program includes investigations of the neutral fraction of orange peel extract with the aim of isolating, characterizing, and identifying those substances, particularly bitter principles, that are most detrimental to the flavor of orange products. Investigations are also in progress on the composition of essential citrus oils as related to flavor of juices, concentrates, powdered juice, and other products; and on investigations of the chemical and physical nature of components of cloud of orange juice to provide better understanding and control of factors affecting stability of orange juice products. Close consultation is maintained with the Florida Agricultural Experiment Station (Citrus Experiment Station, Lake Alfred) and the industry.

Research to develop new and improved food products is carried out at the U. S. Fruit and Vegetable Products Laboratories at Weslaco, Texas, and Winter Haven, Florida. At the Weslaco Laboratory the major applied effort is to develop products which will make greater and more efficient use of grapefruit, as for example, pulp-fortified frozen grapefruit concentrates and grapefruit drinks. This research is being carried out in part in cooperation with several state and private organizations. The cooperators provide fruit or raw materials, such as pulp and juice, of known history. Processing plant facilities are available from the Texsun Citrus Corporation (Weslaco) and Rio-Vac, Inc. (Harlingen). Other research includes investigations to develop new and improved processed products from selected minor fruits, such as avocados, usually in cooperation with, and originating in requests from the State Experiment Station and industry associations. Formal agreements exist with the Texas Agricultural Experiment Station (College Station and Weslaco), with Texsun Citrus Corporation (Weslaco) and with Rio Farms, Inc. (Edcouch). Informal cooperation is maintained with Texas Citrus Mutual, Inc. (Weslaco), Texas Cannery Association (Weslaco) and such other organizations as are found necessary for the procurement and processing of fruit. Research is also underway in the U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida, on the improvement of chilled citrus products. Cooperation is informal with industry.

In the field of new and improved processing technology, research is being carried out at the U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida, to determine how the "foam-mat" type of air-drying can be applied for the preparation of dried citrus products of optimum flavor and stability. This research is being conducted in cooperation with the Western Utilization Research and Development Division (ARS) and the Florida Citrus Commission under a formal memorandum of understanding.

The Federal scientific effort at the Southern Division devoted to research in this area totals 17.9 professional man-years. Of this total 7.5 is devoted to chemical composition and physical properties, 6.7 to new and improved food products, and 3.7 to new and improved processing technology.

The following line of work was terminated during the year: (1) Studies on the chemistry and the mechanism of formation of oxidized flavors in citrus products (under chemical composition and physical properties).

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Related programs of all State Experiment Stations and Industry and other organizations are reported by the Western Utilization Research and Development Division in Summary of Current Program and Preliminary Report of Progress.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Chemical and Physical Properties of Flavoring Constituents of Florida Citrus and Subtropical Fruit Products. Research has been conducted to determine the factors responsible for the formation of oxidized flavors and the chemistry involved, with a view to possibly preventing such off-flavors in commercially produced citrus products. "Citrus oxidized flavor" (COF) also referred to as "cardboard off-flavor" and "castor oil flavor" is not known in freshly prepared citrus products but arises during frozen storage and disappears on further storage. Positive tests for aldehydes were obtained in the volatile materials from off-flavored (COF) concentrate. The odor of off-flavored concentrate was reproduced by the addition to a good flavored concentrate of 1 part per million or less of saturated aliphatic aldehydes of 8 to 10 carbon atoms. This simulated off-flavor disappeared in storage in a manner analogous to the naturally occurring off-flavor.

Improved extraction and recovery methods have shown that total recoverable carbonyl compounds decrease in orange juice and concentrate during storage at the same time that the flavor typical of the freshly prepared product decreases, suggesting that flavor changes may be due in part to loss in carbonyls. At least 6 carbonyls were detected in the extracts. Five of these have been identified as n-heptanal, n-octanal, n-nonanal, n-decanal, and n-undecanal. (S3 2-28).

A new research approach to the study of flavoring constituents and the chemistry of off-flavors of citrus products was recently initiated. The research involves investigations on composition of essential citrus oil as related to flavor of juices, concentrates, powdered juice, and other products, with special emphasis on essential orange oil. The principal flavoring components of orange products are found in the essential oils. In initial research, numerous terpene and carbonyl compounds were separated from essential orange oil and identified. The components identified were: alpha-pinene, camphene, sabinene, myrcene, alpha-phellandrene, alpha-terpinene, d-limonene, gamma-terpinene, p-cymene, terpinoline, carvone, undecanal, dodecanal, n-octanal, n-nonanal, n-decanal, citronellal, geranial, neral, and alpha-terpineol. Commercial orange oil has been separated into terpene fractions in macro quantities (6 pounds) using silicic acid for the purpose of obtaining sufficient material of the four terpenes remaining to be identified. Good progress has been made in characterizing these terpenes. Following the completion of identification of various constituents, the results and techniques will be used to study chemical changes orange oil undergoes under various conditions of storage, handling and processing. (S3 2-36).

2. Investigation of Bitter Principles and Flavonoids in Florida Citrus Products. Undesirable peel substances, including bitter principles, probably cannot be entirely excluded from mechanically extracted orange juices. Nevertheless, identification of these substances could be an important step in effectively limiting the amounts, especially if they could be quantitatively determined. Such methods should be of considerable value in controlling orange juice product quality.

In continued work on a bitter benzene extract of orange peel juice, six crude fractions of differing characteristics were separated. From the largest of these, which was neutral in reaction, a flavone believed to be new was isolated. Subsequent work on its structure showed it to be 3',4',5,6,7-pentamethoxyflavone. Although this compound appears to be about as bitter as naringin when dissolved in alcohol and diluted with water, its concentration in the peel juice is quite low. However, it undoubtedly contributes to the overall taste. The concentration in the peel juice was about 1 gram in 25 liters; while a good grade of grapefruit juice might contain five to ten times that amount of naringin. Added to water in the proportion in which it was isolated, the flavone could not be detected by a taste panel. At twice the concentration its presence was apparent. (S3 2-30).

Recently, a chromatographic system using Supercel columns has been developed which is capable of partially separating the neutral fraction of a benzene extract of orange peel juice into its components. The five distinct portions separated have been tentatively identified as linalool plus terpineol (odor), tangeretin, nobiletin, heptamethoxyflavone, and the pentamethoxyflavone described above. Refinements in the system will be sought.

A midseason peel juice has been found that is not markedly bitter, suggesting the desirability of monitoring peel juice bitterness throughout a season. If a monthly check of peel juices planned for next season shows that bitterness occurs only part of the time, this could furnish valuable information to the industry in adjusting their extractor pressures for optimum quality of juice. (S3 2-37).

Another phase of work has shown that sludge from the winterizing of tangerine peel oil is an excellent source of tangeretin. About 4 gallons of the sludge yielded a little over 2 gallons of oil and 2104 grams of tangeretin. The process involved filtering off the oil and washing the solids with petroleum ether. The solids were then recrystallized from ethanol, washed with aqueous alkali, and again recrystallized from ethanol. (S3 2-30).

3. Factors Affecting Physical Characteristics of Processed Citrus Products.

A stable cloud is considered to be an essential characteristic of high quality orange juice products. Initial research on the chemical and physical nature of components of cloud to provide better understanding and control of factors affecting stability of orange juice products, has been principally devoted to development of methods of preparation and analysis of cloud. Essential oils and lipids are less abundant, and nitrogenous materials more abundant, than was suspected. Remarkable stability of cloud was obtained by extensive reduction of soluble solids by dialysis.

Effort will be directed toward developing more accurate procedures for determining gross composition of the various fractions of cloud, particularly the cellulosic and nitrogenous components. Surveys of the effects on cloud composition of variety, methods of juice extraction, etc. will follow. (S3 2-38).

4. Basic Investigations of Carotenoids in Grapefruit. A thorough knowledge of carotenoid formation in colored grapefruit should provide information useful in improving processing characteristics of, and products from, colored grapefruit. It should also be helpful in developing more highly colored fruit and in retention of color in fruit developed for processing purposes.

Cooperative work with the California Institute of Technology on the biochemical pathways of pigment formation has been terminated. In the joint investigations tomatoes were used instead of grapefruit because of their more rapid rate of metabolism of the carotenoid pigments. Labelled compounds (radioactive) were used in the investigations. Glucose was demonstrated as a carbon source for the carotenes. Acetate is apparently incorporated via mevalonic acid. Glucose is a more efficient precursor of carotenes than acetate though less efficient than mevalonic acid, but only small amounts are incorporated into the unknown colorless compounds. Carbon dioxide is incorporated at about the same ratio as glucose. Glucose and carbon dioxide appear to be incorporated through a 20-carbon precursor (3,7,11,15-tetramethylhexadeca-1,3,6,10,14-pentaene).

The development of chromoplasts in Ruby Red grapefruit has been studied. It was found that shortly after degradation of the chloroplasts, lightly colored birefringent droplets were formed. The droplets increased in color and birefringence and finally assumed a definite shape. While lycopene was the most abundant pigment and was increasing, the chromoplasts appeared as red needles as in tomato fruit. As the lycopene content of the grapefruit decreased and β -carotene content increased, pink platelets were found. They were similar in shape to carrot chromoplasts but different in color. A similar study with white grapefruit indicated that chromoplasts did not form, but even late in development transparent spheres similar in size and shape to chloroplasts could be found. It is considered possible that chloroplasts of low carotenoid grapefruit do not fragment as readily as in colored varieties.

Immediately following the January 9-12, 1962 freeze in the Rio Grande Valley, Texas, cooperative work was undertaken with Crops Research Division, ARS, personnel on the development of a test for freeze damage to citrus trees. The test consists of cutting a 6 mm. plug of bark from a branch to be tested and incubating in 0.5% aqueous tetrazolium red for one hour and noting the color change. It is capable of distinguishing islands of living cells among dead cells and may be useful in basic studies on freeze damage. It cannot predict whether the living cells that have been exposed to freezing temperature will die.

Several other miscellaneous studies were undertaken during the 1961 and 1962 seasons that did not lead to conclusive results but did indicate interesting leads for research. Five of these involved incorporation of labelled carbon dioxide into grapefruit on the tree; attempts to develop a cell-free system for the study of the synthesis of carotenes; pigment analysis of fruit from nucellar red grapefruit trees (cooperative with CR,ARS); effect of artificial cooling of tree on pigment formation in fruit; and investigation of the seasonal changes of lycopene in off-bloom fruit. With respect to the last item, the results indicating that the age of fruit is more important than season of the year in regulating lycopene content of red grapefruit may show that internal factors are more important than external factors in influencing lycopene accumulation or depletion. (S3 2-34).

B. New and Improved Food Products

1. Improved Chilled and Canned Citrus Products. Investigations were completed on the microbiological spoilage of chilled citrus salads. At temperatures above 40°F. the shelf life of the unpasteurized, chilled products, as judged by organoleptically detected spoilage, was too short to permit widespread marketing. Spoilage occurred in 5 to 6 weeks at 40°F. and was little influenced by low levels of benzoate or sorbate as preservatives. At 30°F. the products have a good shelf life which was increased from 12 weeks for the controls to 16 weeks by as little as 0.033% preservative in the cover syrup. Shelf life was not correlated with increase in microbial populations since spoilage was observed at 30°F. with populations below 100,000 per ml.

of cover syrup. At 50°F. plate counts were well over 1,000,000 per ml. before spoilage was detected. Initial plate counts averaged 15,000 per ml. Preservatives were more effective at maintaining low microbial populations than in extending shelf life of citrus salads at the higher temperatures. Evidence was found for the loss early in the storage period of a characteristic fresh citrus flavor. This flavor change was not associated with incipient spoilage. Demonstration that chilled citrus salad products may be kept in acceptable condition for longer periods than are now common in commercial practice, by careful control of temperature and selective use of chemical preservatives, should encourage the improvement of processing and handling conditions with ultimate lowering of costs and increased consumer use.

Factors affecting microbial spoilage, retention of fresh flavor and physical stability of chilled citrus juices are being studied as a basis for developing improved processing practices and improved products with a longer shelf life and a wider distribution potential.

In further experiments to determine the growth rates of pure cultures of known spoilage organisms in the presence of preservatives, addition of even low levels (0.033%) of potassium sorbate to a simulated cover syrup had a noticeable inhibitory effect on both yeasts and bacteria, being considerably more effective against the former. The preservative was significantly more inhibitory at low pH (3.5) within the normal range for citrus salads. Dehydroacetic acid alone or in combination with benzoate or sorbate was more lethal against the organisms than was benzoate or sorbate alone.

In other experiments various preservatives (.033% sodium benzoate, 0.33% of a 2:1 mixture of the methyl and propyl esters of p-hydroxybenzoic acid, and .033% benzoate and .033% ester mixture) were used with or without heat treatment in the 120° to 160°F. range. The addition of preservatives to unheated juice reduced microbial counts. Unheated samples were found to be off-flavor in about 3 weeks; the heated samples in 3 to 5 weeks. Heat treatments to 160° in the presence of preservatives were not more effective than heat treatments without preservatives. Ascorbic acid values decreased during storage (40°F.) to about half the initial value.

Endeavors in other experiments to lengthen the storage life of chilled orange juice with Vitamin K₅ alone or in combination with various anti-oxidants were not successful in the sense that ascorbic acid (Vitamin C) decreases rapidly in proportion to the concentration of Vitamin K₅.

In experiments in progress, variables such as temperature and time of heating, temperature of storage, with and without preservatives, and time of harvest and processing of fruit for juice, are being investigated to determine their respective effects on shelf life and characteristics of chilled orange juice. Preliminary data indicate shelf life is influenced more by temperature of storage than by heat treatment or addition of preservatives. Off-flavors may develop in spite of lack of bacterial growth. (S3 2-35).

2. Improved Frozen Concentrate Citrus Products. Investigations to determine the effect of adverse storage (exposure to temperatures above 0°F.) on the residual storage life of frozen concentrated citrus juices have been completed. In the research, frozen concentrated citrus juices (25 lots of orange, 1 of grapefruit and 1 of tangerine) were collected from commercial processors, 1957-60 seasons inclusive, and tested for stability at 40°F. (household refrigerator temperature) before and after storage at selected temperatures. Sub-lots of each were held at temperatures of 20°, 15°, 10°, 5° and 0°F. for various combinations of times and temperatures sufficiently mild that the concentrates would not show losses of cloud or flavor upon immediate reconstitution.

Cloud stability in concentrates as received varied from 4 to more than 340 days at 40°F., and this characteristic stability was not materially affected by extended storage at 0°F. Exposures to temperatures above zero resulted in reduced cloud stability, and the effects of separate periods of such adverse storage were additive. Concentrates produced after a major freeze, in the 1958 season, possessed cloud stability comparable to that of other concentrates. Those produced in the 1957 season exhibited flavor stability equal to or greater than their cloud stability, but the cloud stability of the 1960 concentrates greatly exceeded their flavor stability. It appears that heat stabilization of concentrates produced by high-yield juice recovery methods was more effective with cloud than with flavor.

Information developed in this study has commercial application, in that it emphasizes the desirability of keeping the product temperature low during distribution. It will also aid the distributor in assessing probable damage caused by unavoidable increases in temperature.

In another series of experiments, frozen concentrated orange juices, at different density levels, were stored at 20°, 15°, 10°, and 5° F. and evaluated for cloud and flavor stabilities. When fresh juices low in enzyme activity were made into concentrates, higher concentrations alone were effective in increasing cloud stability. From 43 to 60° Brix cloud stability increased with concentration with or without heat treatment, but the cloud stability of the juices was further increased by heat treatment at 150° F. Not only did the cloud stability increase with concentration but at the higher densities small increases in concentration increased stability more than equivalent increases at lower density levels. Taste panel evaluations of concentrates indicated very little improvement in flavor stability with increased concentration. The 150° F. treatment did not increase flavor stability consistently at any level of concentration. Concentration was more effective as a method of increasing cloud stability than as a method of increasing flavor stability.

The leaves of domestic muscadine grapes and of wild grapes were found to contain a water soluble material which will inhibit pectinesterase activity and add stability to the cloud in orange concentrate. Control of pectinesterase activity in this manner without heat treatment of citrus products may be of both practical and theoretical importance, but requires further investigation.

3. Development of Pulp-Fortified Grapefruit Products and New Grapefruit Based Beverages. Because red grapefruit represents a large portion of the total production (some 65 percent of the 1960-61 Rio Grande Valley citrus crop), practical procedures have been sought for producing highly colored frozen grapefruit juice concentrates and other grapefruit drinks from colored grapefruit by fortification with pulp from the colored fruit. These products should have increased consumer appeal and provide new or extended outlets for the fruit.

Mid season and late season packs (1960-61) and an early season pack (1961-62) of pulp-fortified red grapefruit juice concentrates were prepared, stored, and evaluated for color, cloud retention and taste. The improvement of the color of the reconstituted concentrate by the use of high pulp cutback juice in the preparation of the concentrate was repeatedly demonstrated. The addition of this pulp had an adverse effect on cloud retention which could be overcome by heat treatment of either the low pulp evaporator feed juice (mid season) or the heat treatment of both the low pulp evaporator feed juice and the high pulp cutback juice (early and late season). The addition of this pulp also caused gelation which could be overcome by heat treatment of either the low pulp evaporator feed juice or the high pulp cutback juice, or both. There was no apparent detrimental effect on taste due to the heat treatment necessary to offset the adverse effect on cloud and gelation of addition of high pulp cutback juice. Due to the freeze of January 9-12, 1962, which prevented a full season's work, these observations should be rechecked through another season under carefully controlled conditions, when normal fruit becomes available. The 1960-61 findings showing the favorable possibilities of red grapefruit concentrate were factors in encouraging the construction of three new concentrate plants in the Rio Grande Valley prior to the freeze.

Preliminary experiments have been initiated to develop new drink formulations using grapefruit juice as a major component of blended drinks or punch concentrates. Grapefruit-based berry or fruit flavored drinks show promise. (S3 2-33).

4. New and Improved Products from Texas Oranges and Minor Fruits. During the past several years increasing numbers of orange trees have been planted in the citrus producing area of Texas. Data have been obtained on the seasonal variation and juice quality of Valencia, Hamlin and Marrs fruit to guide processors in the efficient production of concentrates and other juice products.

Variations in the juice quality of Valley-grown Valencia oranges were followed by weekly samplings of fruit from two locations for about 4 months of the 1960-61 season. The yield of juice showed little variation during the testing period. Acid values declined during the period; while Brix values increased sharply during the early weeks, leveled off during the mid season, and remained at about the same level for the last half of the period. The Brix-acid ratio increased during the test period, due primarily to the steady decrease in acid values. The solids-per-box and solids-per-ton values had the same trend of variation as the Brix values since the yields of juice were fairly constant. Little variation in juice quality and yield was noted between fruit from the two groves tested. The color of all samples was good. The trends of variation in juice quality were essentially the same as those reported for Florida Valencia oranges.

Similar type data were obtained for Hamlin and Marrs oranges harvested at weekly intervals from two locations over a 3-month period in the 1961-62 season. The low acid, Brix and color values noted for juice from Hamlin oranges indicates that a high quality juice product could be prepared from this variety only by blending a large quantity of juice from another variety such as Valencia. Juice from the Marrs oranges showed higher Brix and color values, but the low acid values indicate that this variety should also be blended with a variety such as Valencia.

The juice yield, citric acid content, and ascorbic acid content of the oranges decreased rapidly after the freeze of January 12, 1962. Hamlin and Marrs, the more mature varieties on this date, showed the greatest loss, while Valencia, a later maturing variety, had the smallest percent of decrease. (S3 2-23).

An improved, inexpensive, and easily prepared guacamole (avocado salad mixture), which employs ordinary commercial cracker meal to improve the consistency of the thawed product, and which can be frozen and stored for as long as 12 months at 0°F. has been developed. The mixture may be prepared by a commercial processor interested in volume sales or by the housewife from her home-grown avocados. Such a product extends the outlet for avocados in the processed form.

Previous experiments had developed formulas for products in which separation of a watery phase after freezing and thawing was successfully retarded by using ingredients such as waxy rice flour, sodium alginate or other thickening agents. While these ingredients are suitable for the commercial processor, they are not readily available to the housewife. Now it has been found that the separation may be overcome simply by adding cracker meal, a common commercial product in retail distribution. (S3 2-23).

C. New and Improved Processing Technology

1. Application of Foam-Mat Drying to Florida Citrus. With the cooperation of the Florida Citrus Commission and the Western Utilization Research and Development Division, a complete integrated pilot plant for investigation of foam-mat drying of citrus juices to produce citrus powders of optimum flavor and stability was designed, installed, and placed in operation at the Winter Haven Laboratory. In the foam-mat process, a fluid material citrus concentrate, is mixed with a small amount of edible stabilizer. The mixture is whipped into a foam and then extruded as small ribbons onto a moving belt, and air dried.

Good progress has been made in research on foam-mat drying of orange concentrates, particularly in establishing maximum tolerable temperature and time relationships in drying, in relative humidity-moisture relationships in dried powders, and in initiating storage studies. Equipment modifications have been made to increase useful air temperatures and improve temperature control. Investigations initiated also include the evaluation of foam stabilizers with respect to their effects on flavor, stability, and reconstitution; inert gas packaging; secondary drying; volatile components of orange powders; and the exploratory preparation of grapefruit powder. Two studies completed are reported in the following paragraphs.

The equilibrium moisture contents of two "Foam-Mat" dried orange juice powder products were obtained in the lower range at relative humidity for 50°, 70°, 80° and 100°F. storage. One orange juice product was stabilized with 0.8% modified soya protein and 0.2% methyl cellulose on a solids basis, while the other contained 1% monoglyceride. In general it was indicated that a relative humidity of about 6% would be satisfactory to handle monoglyceride powder of 1% moisture content, while even lower humidities would be required for modified soya protein stabilized powders. Both types of powders with 2% moisture content could be handled in 15% relative humidity, except modified soya protein stabilized material at 50° F. which would require a lower humidity. A 10% relative humidity was adopted for the handling of these powders, as this provides a margin of safety to cover such adverse conditions as dehumidifying equipment failures for brief periods, or overloading of this equipment because of excessively high humidities in the surrounding atmosphere. Both orange juice powder products have a tendency to cake when adsorbing moisture. From observations in processing this tendency increases as moisture content increases.

An evaluation of the effects of drying times and foam temperatures on the initial quality of the dried products was made. A modified soya protein-methyl cellulose foam stabilizer, found to result in better appearance of the powder and reconstituted juice, was used in place of the conventional monoglyceride type stabilizer. Maximum foam temperatures during drying were 160°, 170° and 180°F. Products dried at 160°F. for 11.7 to 26.2 minutes were of good flavor and varied in moisture content from 4.55 to 2.71 percent. Those dried at 170°F. for 10.5 to 13.1 minutes contained 3.99 to 3.37 percent moisture

and were of good flavor. Flavor changes were observed in products dried for longer periods. Powders dried at 180°F. for 8.8 to 13.1 minutes contained 4.03 to 2.46 percent moisture and were of good flavor, while changes were observed in those dried for longer periods. The majority of the powders prepared in this study were of good flavor. Only those dried at the higher temperatures using drying periods in excess of 13 minutes differed in flavor from that of the reference control. (S3 2-32).

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PROCESSING AND PRODUCTS

Western Util. Research & Development Div., ARS

Problem. The economic stability of the citrus and subtropical fruit industries in the Western Region is dependent upon effective utilization of fruit that cannot be accommodated on the fresh fruit market. The utilization of surplus or wholesome but blemished fruit provides the margin necessary to assure adequate returns to the farmer and continued development of stable markets. Ineffective utilization of products and continuously increasing processing costs are resulting in decreased returns to the growers. The California-Arizona grapefruit industry is encountering difficulty in disposing of both fresh fruit and processed grapefruit products. The pineapple and subtropical fruit industry in Hawaii must find practical methods for processing its products for export in order to prevent the accumulation of burdensome surpluses. The navel orange industry in California is hampered by the unavailability of satisfactory processes for the utilization of navel oranges. Juice extracted from early fruit, and during some seasons from essentially all of the navel oranges, contains unknown substances that impart an intolerable bitter flavor to juice products after mild heat-processing or after standing at ambient temperature for a short time. Large new plantings of navel oranges may be expected to aggravate the utilization problem. Deterioration of the flavor and color of these and other processed citrus and subtropical fruit products imposes severe limitations upon the economic stability of the industry.

Information is needed on the chemical composition of citrus and subtropical fruits and their products and byproducts as a basis for the development or application of new and improved methods of processing; and for the production of new and improved food and industrial products and pharmaceuticals. Special attention needs to be given to the nature of the chemical changes involved during pre-treatment, processing and handling which lead to the formation of off-flavors, -colors, and -odors in processed products.

USDA PROGRAM

In the Western Utilization Research and Development Division, a concentrated program of fundamental research on citrus and subtropical fruit and its application to industry problems is conducted at the Division headquarters at Albany, California and at the Fruit and Vegetable Chemistry Laboratory in Pasadena, California. Investigations are conducted on the composition of citrus essential oils,

flavonoid compounds and other citrus constituents that are related to off-flavors and darkening of citrus products, the natural flavor components of oranges, enzyme systems that are involved in the appearance and disappearance of constituents and structures of plant tissues, constituents of dates that affect the quality and stability of products, and the application of findings of such research to the development of new and improved citrus and sub-tropical fruit products.

The Federal program of research in this area totals 17.7 professional man-years. Of this number, 15.7 are assigned to chemical composition and physical properties (including one employee whose salary is provided by the Date Administrative Committee and two employees whose salaries are provided by a trade association, The Lemon Products Technical Committee), and 2.0 to new and improved food products.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations, in 1961, reported 20.3 professional man-years divided among subheadings as follows: Chemical composition and physical properties 13.7, new and improved food products 2.0, new and improved processing technology 3.6, and new and improved industrial products and feeds from byproducts of citrus and sub-tropical fruit processing (including waste disposal) 1.0. Basic studies are concerned with enzymes and enzyme substrates of citrus and subtropical fruits and reactions that influence the character of food products; with flavor constituents of oranges, and with the chemistry of processed olives. A lesser effort is expended on development of new and improved products and processing technologies including stabilized frozen concentrates, flavor recoveries, bacteriology of products, and recovery of valuable materials from processing wastes.

Industry and other organizations, including citrus and subtropical fruit processors, beverage and beverage-base manufacturers, equipment and container manufacturers, and flavoring manufacturers, conduct research and occasionally contract with private research institutions for special projects. They are entitled to exclusive use of data obtained or products or processes developed. Projects are also developed cooperatively with federal or other non-private research groups, in which case the results become public property. Much research of industry is concerned with applications of fundamental research findings of public institutions, or with answering

specific problems of industry, such as developing suitable containers, improving product formulations and introducing new formulations to the market. Estimated annual expenditures in this area are equivalent to approximately 130 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Citrus Essential Oils. The chemical composition and physical properties of citrus essential oils determine the quality and stability of food products made from them. Fundamental studies of citrus oils are continuing with support of the Lemon Products Technical Committee, which provides the salaries of two scientists assigned to the project. The major cause of instability of lemon oil was demonstrated to be the oxidation of gamma-terpinene to para-cymene, disproving the widely held hypothesis that para-cymene is a breakdown product of citral. This finding not only explained the failure of previous attempts to stabilize lemon oil against the development of "cymey" off-odor, but suggested new approaches to stabilize products. In the laboratory, gamma-terpinene was removed from lemon oil for an evaluation of stability by a commercial user. The modified product was reported to be 2 to 3 times more stable than an untreated control sample. Stabilizing lemon oil would make it useful in many products that cannot carry ingredients with rapid deterioration rates. Studies have also included analyses of monoterpene hydrocarbons and identification of esters and alcohols of citrus oils. Data obtained are useful in determining authenticity of lemon oils in commercial channels of trade, and may help identify source of oils. In addition, the data provide knowledge on the importance of these compounds to the flavor of citrus oils and their products. It has been demonstrated that alcohols may be artificially formed from monoterpene hydrocarbons during certain stages of processing such as in cases where the lemon oil comes in contact with the highly acid lemon juice. Thus, important contributors to flavor could be lost or reduced in intensity. It should be possible, now, to develop processing methods to reduce the conversion.

2. Citrus Fruit Composition. The color stability and flavor of citrus products are related to the flavonoid compounds found in juice. Some flavonoids, such as those in grapefruit and Seville oranges, are extremely bitter and impair the marketability of citrus products. A chemical change in flavonoids can cause a dark discoloration in processed juice products. A glucoside, phlorin, which had never before been reported as a natural constituent in plants, was isolated from oranges and grapefruit and

shown to be present in lemons. This compound is important because it turns brown in the presence of amino acids under certain pH conditions, and could be responsible for product deterioration.

New basic information has been obtained on the compounds that are most closely related to bitterness in citrus products. Certain of these intensely bitter compounds (flavonoids) can be made to undergo a chemical change that converts them to very sweet compounds (dihydrochalcones). So sweet are these compounds that they have potential commercial significance as low-calorie food sweeteners, and preliminary pharmacological tests have been run, which show these chemically-altered citrus compounds to be relatively non-toxic. Other related flavonoids are not bitter and do not become sweet by this type chemical alteration. Thus, naringin and neohesperidin are very bitter and form dihydrochalcones that are very sweet; while hesperidin, eriocitrin, naringenin rutinoside, and isosakuranetin rutinoside are tasteless and form dihydrochalcones that are also tasteless. The difference in chemical structure relating to these bitter and sweet flavors was elucidated. In the complicated molecular structure of these compounds, the characteristics of the chemical linkage between two sugars (rhamnose and glucose), determines whether or not the flavonoid will be bitter and the dihydrochalcone will be sweet.

Another bitter principle of commercial significance to the citrus industry is that which develops in Navel orange products on standing. This bitterness is related to limonoid compounds, which are commonly found also in citrus seeds, and which are now being investigated. Laboratory procedures have been adapted to this study and preliminary identification of specific compounds in Navel oranges has been made. Knowledge of such compounds is required in order to understand the nature of bitterness development in orange products and to seek means for its prevention.

3. Fruit Flavor Components. Of great importance to flavor chemistry in recent years has been the application of gas-liquid chromatography techniques. High instrument sensitivity was achieved by use of dual columns with dual-flame ionization detectors and programmed temperature control, so that it is now possible to separate and make tentative identifications of important volatile components from the headspace atmosphere of a small flask containing only a gram or two of the food product under investigation. The procedure, developed at Albany, California is sufficiently distinctive to warrant a special name. The instrumental record developed by the new procedure is called an "aromagram." Earlier extraction and concentration procedures are not required so that possibility of introducing artifacts is minimized. Sample size required is very small and food samples can be withdrawn from

processing lines at different stages or from packages during storage experience and analyzed for compositional changes that may be correlated with subjective evaluations of products. The aromagram procedure is more sensitive by a factor of ten than any method previously used. However, while this is below the sensory threshold of many flavor components, it is not sensitive enough to detect some odorous compounds at levels detectable by the human nose. Only a beginning has been made in using the aromagram in fundamental studies of fruit flavor. The complicated mixture of volatile components from oranges is being identified. In order to evaluate the flavor contribution of specific compounds, isolated substances from orange flavor essence are added individually to an orange powder which was prepared so as to prevent development of off-flavors. Evaluations are made by organoleptic, test panel methods. This work is closely connected with efforts to develop a new orange powder of superior flavor (see paragraph B, 3).

4. Composition of Dates. Darkening of dates, as they proceed through trade channels, damages their salability and reduces markets. Investigations are supported in part by the Date Administrative Committee (operating under a Federal Marketing Order) which supplies the salary of a scientist assigned to this work. Earlier work on enzymatic conversion of date sugar in order to improve product texture has been reduced to commercial practice. Current investigations are revealing the chemical nature of some of the components of dates that are known to brown under certain conditions. Three general chemical systems of discoloration have been revealed. These are enzymatic browning, indicated to be of limited duration in stored fruit, oxidative browning, and nonoxidative browning. Both of the latter two deteriorations are of long-term storage importance because of the relatively high concentration of reacting compounds. A better understanding of these reactions must be obtained in order to seek a rational control of date discoloration.

5. Texture of Fruits. Little is known of the enzymes involved in the formation of cell wall polysaccharides of plant tissue. This, in part, is due to the dearth of knowledge of the cell wall constituents themselves. Work in this complex field has been initiated, using an enzyme preparation obtained from germinating mung beans. By use of radioactive tracer techniques, the enzyme preparation was found capable of forming two polysaccharides from glucose and fructose. One of the polysaccharides was soluble in hot water, the other not. The former is apparently formed by a previously unrecognized enzymic pathway with the glucose

incorporated into the polysaccharide, intact. This polysaccharide is unusually resistant to acid hydrolysis. This study has further offered a clear insight into the nature of an alternative pathway of glucose metabolism bringing a new enlightenment to the way higher plants utilize carbon sources for cell wall synthesis.

6. Ascorbic Acid Biosynthesis in Plants. L-ascorbic acid (Vitamin C) occurs in all higher plants but little is known of its biosynthetic origin, its function, or the nature of its accumulation in fruits and vegetables. The enzymes involved in these processes are being studied by radiotracer techniques in which precursors of ascorbic acid are labeled with C^{14} and fed to living plant tissue. Ascorbic acid, later isolated from the plant, demonstrates by the amount and pattern of its radioactivity the pathways by which the vitamin is formed. It has been proven that glucose is converted, in strawberries, to ascorbic acid and not to an isomer, D-arbo-ascorbic acid as suggested by other researches. The net result of this has been to demonstrate that plants possess the astonishing capacity to convert a D-sugar to L-ascorbic acid by changing the configuration about a single carbon atom. Interrelationships are being elucidated among glucose, galacturonic acid (the main building block of pectins and important in textural quality of fruits), methyl ester of galacturonic acid (an important compound in the textural quality of fruit products), and ascorbic acid. The methyl ester of galacturonic acid is a better precursor of ascorbic acid than is the acid itself. On the other hand, both the acid and its ester function in pectin synthesis and both undergo reduction to the same compound, galactonic acid.

7. Enzymes Involved in the Ripening of Fruits with Ethylene. The effects of ethylene gas on maturation rates of harvested fruits in storage have been known for some time. The knowledge has served as a basis for controlled ripening of lemons and bananas, and accumulation of ethylene has an adverse effect on fruits to be held for long periods in cold stores. Basic research is under way to learn the biochemical nature of the ethylene effect on maturation of fruits so that its function can be better controlled and made more useful. The avocado was selected as an example fruit to study because it is available the year around, is a good producer of ethylene, and has a strong response to ethylene treatment. Avocados are exposed during maturation to ethylene synthesized with radioactive carbon or hydrogen. The labeled ethylene reacts in the maturing fruit and analyses are made to determine the reaction products. When avocados were ripened in the presence of hydrogen-labeled ethylene, 15% of the label was found in the hydrocarbon, toluene. The establishment of this hydrocarbon as a major reaction product indicates an unusual, perhaps unique, metabolic pathway involved in maturation.

B. New and Improved Food Products

1. Citrus Essential Oils. Compositional studies of citrus essential oils, supported in part by the industry (see paragraph A, 1), are applied to problems of stability of products and of establishing the authenticity of oils in trade channels. Cooperative studies are conducted as a bridge to such extension activities between basic research and commercial practice. Techniques to produce a lemon oil without gamma-terpinene were developed and led to the commercial production of a stabilized oil using another, privately-developed method. Ratios of concentration of certain natural carbonyls in lemon oil have been found to be sufficiently characteristic to be useful in identifying spurious products offered for sale as lemon oil. A deterioration of flavor-contributing terpenes to alcohols has been observed under conditions of lemon oil recovery from peel or emulsions pressed from peel. Means for avoiding this quality loss during processing are under investigation.

2. Improved Date Products. Dates of softer texture and improved flavor can be produced from inferior quality dates by treatment under conditions that are optimum for the action of the enzyme invertase. Sucrose is inverted to fruit sugar and glucose under these conditions. This process was developed in the laboratory, supported in part by the industry (see paragraph A, 4), and has now been extended to commercial practice. Approximately 1,000,000 pounds of dates are so treated annually. If the labor-saving practice of harvesting all dates from a tree at one time is greatly extended, the portion of the crop needing this inversion treatment to improve quality should increase materially.

3. Foam-mat Drying. Over 50 agricultural commodities have been successfully dehydrated by the foam-mat drying process invented by Department engineers at Albany, California. These include orange, grapefruit, and lemon juices. Continuous, automatic equipment has been designed and constructed for continuing experimental studies. A commercial drier of similar design has been installed in a food processing plant in California and several other industry applications of this novel dehydration method are being investigated with pilot operations to develop commercial-scale equipment. Most products tested can be dried at atmospheric pressures without off-flavor development or discoloration. There is a loss of volatile flavor components. A major problem in the technology of each product so dried is to find means for adding back or redeveloping

flavor. Solid carriers, such as sugar and other carbohydrates are used to "lock in" volatile flavor components and equipment has been designed to mix and form the carbohydrate-flavor mixture. This equipment operates continuously and has advantages over previous methods by minimizing heat requirements, thereby minimizing chemical alteration of the volatile flavor components. Improved foam stabilizers, required for some products in foam-mat drying have been selected or developed to improve product quality. Drying cycles have been determined for specific products to prevent serious quality loss during processing and to increase heat and moisture transfer and mechanical efficiencies so that processing costs may be reduced. Cooperation has been given to the Winter Haven, Florida field station of the Southern Utilization Research and Development Division in applying the foam-mat drying process to orange juice.

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III. MARKETING RESEARCH

MARKET QUALITY

Market Quality Research Div., AMS

Problem. Research is needed on the measurement of quality in citrus and other subtropical fruits. With a better understanding of quality characteristics and objective indices for the measurement of quality, grades and standards would be more meaningful and could be better enforced. In addition instrumentation for quality measurement lends itself to ultimate automatic devices for quality sorting on a commercial basis. Fruit soilage and wastage resulting from post-harvest decays of citrus fruits present serious problems in both domestic and export markets. Much research is needed to relate handling practices, packaging, precooling and transit refrigeration to decay and soilage, and to develop and evaluate physical and chemical treatments for decay reduction. Research is also needed on the storage of citrus fruits. Optimum storage temperatures for the principal varieties of oranges produced in different areas need further investigation. There is also a vast field for research on controlled atmosphere storage for oranges, grapefruit and lemons. Problems exist in each of the geographical areas which are sometimes distinct and sometimes interrelated, but which require biological research in the separate production areas for solution. Several species of common stored-product insects attack dried citrus pulp animal feed and may build up tremendous populations. In some cases wholesalers and retailers have refused to handle the product because the excessive insect infestation creates a hazard to other commodities in stock. There is an urgent need for effective preventive measures to be used in warehouses that will not leave hazardous residues in the feed, and for the development of packaging that will resist insect infestation of the product in marketing channels.

USDA PROGRAM

The Department has a continuing program involving largely applied research performed by horticulturists, plant physiologists, plant pathologists, and food technologists. The work is conducted in the producing areas of California, Florida and Texas. Market studies are made in New York City and Chicago. A P.L. 480 grant for research on chemical and physiological variables in avocado and papaya fruits during ripening and storage has been made in Columbia, South America. Studies on objective measurement of quality are conducted under contract by the California Agricultural Experiment Station. The work on avocados, mangos, and limes is done in cooperation with the Florida Agricultural Experiment Station. The work on storage and

export shipments of grapefruit is conducted in cooperation with the Florida Agricultural Experiment Station, the Florida Citrus Commission, and the Foreign Agricultural Service. The work on papayas is in cooperation with the Hawaii Agricultural Experiment Station. The biphenyl work is conducted in cooperation with the California Citrus Research Committee. Irradiation research is done in cooperation with the Quartermaster's Food and Container Institute.

Total federal professional man years devoted to this area is 13.3. Of this 1.6 is devoted to objective measurement of quality; 3.1 to quality maintenance in storage; 3.1 to quality maintenance during transportation; 0.7 to post-harvest physiology; 4.3 to post-harvest disease control; and 0.5 to program leadership. A PL-480 project recently initiated in Columbia involves \$64,145 equivalent in pesos over a 3-year period.

Work terminated during the period included studies on rind breakdown in citrus fruit, fungicidal methods for control of Florida citrus, export tests of California citrus, truck shipments of western citrus, seasonal changes in Marcott Honey oranges, maturity measurement in avocados, automatic sorting of dates for moisture content, and storage of Pope's summer oranges.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

In 1961, the State Experiment Stations reported 13.9 professional man years divided among subheadings as follows: Objective measurement and evaluation of quality 4.6, handling and packaging 1.2, storage 1.7, transportation 0.1, post-harvest physiology 2.4, and disease control 3.9. Measurement and evaluation of quality includes size, shape and appearance of avocados with respect to quality; physical, chemical, and organoleptic properties of citrus oils on flavor stability; enzymatic activity; gelation of citrus juices; relation of environment, cultural properties, and maturity on quality; isolation and identification of volatile compounds affecting quality; and influence of plant regulators on quality of fruit. Handling and packaging includes time-temperature studies, coating materials, pre-cooling, and physiological and biochemical changes. Storage work includes physical and chemical changes; effects of mineral nutrition on metabolic changes in storage; and microorganisms of stored juices. Transportation work includes cause and control of brown rot in lemons, and composition studies of avocados. Post-harvest physiology includes the biochemistry of maturation of avocados, and the physiological, chemical, and enzymatic changes in citrus. Disease control includes effects of rapid cooling as related to control measures and a study of fundamental differences between susceptible and resistant fruits.

Industry and other organizations. Research by chemical companies on products to control decay of citrus fruit amount to an estimated annual expenditure equivalent to approximately 2 professional man years. Similarly a large cooperative in California does research on disease control, packaging and transportation amounting to about 2 man years, and the Florida Citrus Commission about 1 man year on packaging and decay control.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Study of Seasonal Changes in Quality of Murcott Honey Oranges for Use in Developing Maturity Standards. (Florida) Palatability in the Murcott Honey orange changed from unacceptable in December to prime eating quality in February and March, and dropped slightly in April. Total solids increased in a similar fashion. Total solids-to-acid ratio, pH, fruit weight, and volume of juice increased with maturity and ripening on the tree, while ascorbic acid and total acid dropped throughout the season. Fruit grown on sour orange, Cleopatra, and sweet orange rootstocks were of better quality than those on rough lemon. A report on this work will soon be published.
2. Relation of Physical Properties, Chemical Composition and Metabolic Activity to Market Quality of Citrus. Studies were conducted in Florida to determine if Valencia oranges could be sorted by light transmittance techniques according to their need for degreening so that oranges would be held with ethylene at high temperatures for only the minimum length of time necessary for degreening. Treatment based on need for degreening should reduce decay and rind disorders.

Two tons of early Valencia fruit were separated into four groups according to the amount of green pigment in the rind. Twenty-five percent of the fruit were well colored and required no ethylene treatment. Twenty percent required between 16 and 40 hours degreening with ethylene. About 24 percent were satisfactorily degreened in 48 hours while those fruit classed as the greenest (31 percent) did not degreen satisfactorily in 64 hours.

Quality separation was also achieved in these tests. Green fruit sorted by the light transmittance instrument had an average Brix/acid ratio of 9.8 while the progressively less green fruit had average ratios of 11.7, 12.6, and 14.4, respectively. Non-separated fruit averaged 12.5.

The research contract with the California Citrus Experiment Station on changes in metabolism of oranges during maturation has progressed satisfactorily. Two incubation series for labeled sucrose, glucose, acetate, carbon dioxide, and phosphate have been completed. No significant findings which can be related to maturity evaluation in oranges are evident as yet.

Tests were made in Florida with an instrument for measuring firmness of individual fruits. With adequate procedures repeated tests can be made without damaging the fruit. Preliminary studies were made on changes in firmness as a result of various treatments. Grapefruit softened in storage and also with maturity. Ethylene treatment accelerated softening.

3. Development of Maturity Measurements in Avocados. From June 1960 to January 1961, over 1,000 avocados, representing 9 varieties, were studied in Florida. Except for the Taylor variety, oil content in the fruit was similar to that found during previous seasons. Oil content increased as the season progressed; however, variation in oil content among individual fruits was so great that it precluded the use of this method in determining maturity.

4. Development of Method and Equipment for Automatic Sorting of Dates for Moisture Content. This work was conducted under contract in California. The contractor has completed and tested the demonstration model of a date sorting machine. This machine provides four moisture classifications: (1) 17 percent or less, (2) 17 to 21.5 percent, (3) 21 to 25.5 percent and (4) over 25 percent. It is capable of sorting dates at a speed of four dates per second. The machine has been tested in a date-processing plant and has been shown to meet the requirements of the date processors.

B. Quality maintenance in storage

1. Controlled Atmosphere Storage of Citrus Fruit. Experiments were continued to extend the storage period of Texas red grapefruit by controlling the storage atmosphere. Pretreatment for 4 days at 80°F following harvest was effective in reducing decay and pitting in fruit stored early in January but not in fruit stored in late November. This treatment also reduced decay of fruit held in air.

Decay was of no importance in any of the lots during the first 98 days storage. At the end of 140 days, January-harvested fruit stored at 41°F was 32 percent decayed and November-harvested fruit, 74 percent. However, when stored at 46°, losses of January fruit were only 5 percent and of November fruit, 9 percent.

Washington navel oranges were stored in California up to 4 months in 5 percent oxygen and no carbon dioxide, and in 5 percent oxygen and 5 percent carbon dioxide at 40°F. Flavor and appearance were retained well in the atmosphere containing 5 percent oxygen and no carbon dioxide, but the flavor was impaired in oranges held in the atmosphere containing 5 percent carbon dioxide. Oranges stored in normal air retained flavor quite well, but deteriorated in appearance because of shrinkage and dullness. Decay was much more prevalent in oranges stored in controlled atmospheres than in comparable fruit stored in air.

2. Storage of Pope's Summer Oranges. (Florida) Pope's summer oranges stored 2 and 3 months at 32°F developed much less decay and rind breakdown during the subsequent 7-day holding period at 70° than fruit stored at 38°F. In 1960, oranges picked in April had less decay after storage than fruit picked in May. The use of 1 percent Dowicide-A and $\frac{1}{2}$ percent hexamine with a wax reduced the occurrence of decay during the holding period after removal from 38°F storage. Fruit picked in April 1960 and May 1961, with solids-to-acid ratios of 18.5-to-1 and 17.5-to-1, respectively, maintained their internal quality during the storage and holding period. Storage off-flavors developed in fruit picked in May 1960 with a solids-to-acid ratio of 23.4-to-1 at harvest.

3. Ripening and Storage of Florida Mangos and Avocados. The most satisfactory temperature for mango storage still appears to be 60°F. Skin color becomes bright at this temperature. Fruit slowly softens (2 to 4 weeks) at this temperature and the flavor of the softened fruit is tart. Ripening at 70° to 80° for 1 or 2 additional days then is necessary for the fruit to become sweet and of good quality. Fruit displaying a color break will withstand storage temperatures below 50°F without becoming injured while those with no color break become injured.

A temperature of 55°F still appears to be both a safe storage and ripening temperature for most avocado varieties. Some varieties developed chilling injury at 50°F.

4. Factors Influencing the Storage and Shelf Life of Florida Persian Limes. Limes dipped in polyethylene emulsions were greener and fresher in appearance than controls after 10 days at 70°F. Limes held at 50°F for 1 month in unventilated polyethylene bags retained a fresh green appearance better than those not bagged but had more decay.

C. Quality maintenance during transportation

1. Prestorage Treatments and Simulated Transit Temperatures for Florida Grapefruit. Studies were conducted to determine the best transit temperature for Florida grapefruit exported at different seasons of the year. Sixty degrees was found to be the best temperature for Marsh Seedless and Ruby Red grapefruit harvested in October and December. Excessive pitting and decay developed on October harvested grapefruit during the 3-week simulated transit period at 40° and 50°F and the subsequent 2-week 70° holding period. October- and December-harvested fruit held at 32° developed considerable brown staining during the 2-week 70°F simulated marketing period which detracted from the market appearance.

In the fruit harvested in March, little differences were noted in the keeping quality of the grapefruit held at 50° and 60°F. Excessive decay and pitting developed on fruit held at 32° and 40°F. Excessive decay developed in May-harvested fruit at all temperatures; however, grapefruit held at 50° and 60°F had the least amount of pitting and decay.

Washed (but not waxed) grapefruit harvested in October and December developed good color during the 2-to 3-week simulated transit period at 60°F. No pitting and little decay developed under these conditions. When this early grapefruit was waxed, a minimum of 36 to 38 hours of degreening was required for good color to develop.

2. Export Shipment of Florida Grapefruit. In an April test shipment of grapefruit to Hamburg, temperature and humidity aboard ship were accurately maintained in refrigerated stowage but fluctuated in ventilated stowage. No commercially significant rind breakdown developed during the voyage or during the 2-week holding period at 60°F.

Marsh Seedless grapefruit stowed in a refrigerated hold at 50°F arrived with about 1 percent decay, while those stowed at 60° arrived with about 4 percent decay. After storage at 60° for 7 days, the 50°-stowed fruit had about 3 percent decay, and the 60°-stowed fruit had about 8 percent decay; after 14 days the former had about 5 percent, the latter about 13 percent.

Marsh Seedless grapefruit stowed in the ventilated hold (average temperature between 50° and 60°) arrived with about 3 percent decay and developed about 6 percent decay after 7 days at 60°F, and about 11 percent decay after 14 days at 60°. Although the Ruby Red grapefruit followed the same decay pattern as the Marsh Seedless, decay was considerably less, probably due to source differences. Green mold was the frequent disorder on arrival, which indicated fruit injury had taken place. Stem end decay predominated during the 2-week holding period at 60°.

3. Truck-Rail Tests (Cooperation with T & F) Four truck-rail piggy-back tests from Florida under ventilation service showed a need for improved loading pattern, modification of the front bunker to provide forced air through longitudinal channels in the load, and the development of a method by which air can be directed into the trailer when the rear of the trailer faces forward, as is often the case after loading on a rail car.

Five truck-rail test shipments with mechanically refrigerated units provided good peripheral cooling but heat from the center of the load was removed slowly.

4. Maintaining the Quality of Hawaiian-Grown Papayas During Shipment to Continental United States. Three test shipments by ship and three by plane were conducted during the year. Papayas shipped by air remained salable about 2 days longer than those transported by ship. Precooling extended the salable life 1 day. Hot water treatment reduced decay by about one half compared with the ethylene dibromide treatment.

D. Post-harvest physiology

1. Cause and Prevention of Rind Breakdown in Citrus Fruits. Tests in Florida indicated that desiccation alone by exposure to high temperature, low humidity, and high air flow did not produce rind breakdown in oranges. However, rind breakdown of oranges was produced by a delay between harvest and washing. The amount of rind breakdown increased with the length of delay and with the amount of time fruits stayed on the brushes in the packing line. Pineapple and Murcott Honey oranges were more susceptible than Valencia oranges. High temperature and low humidity during delays after harvest increased susceptibility of Valencia oranges. Post-harvest application of fungicides increased the incidence of rind breakdown only slightly and caused no rind breakdown when the fruit was treated on the day harvested. A report on this work is being prepared for publication.

Experiments were continued in Texas to find the cause and control of rind-oil spotting (Oleocellosis) in Marrs Early Orange. A correlation was found between the evaporation rate at 2:00 p.m. from a black porcelain atmometer placed in the orchard and the spotting susceptibility of fruit picked at the same time. High evaporation rates were associated with low susceptibility to spotting. However, rind-oil spotting was not very prevalent during the 1961 season, and there were not sufficient samples representing great susceptibility and/or low evaporation rates to consider this correlation conclusive. Growers and shippers who have followed recommendations to pick Marrs Oranges only in the afternoons of clear, sunny days, and defer picking after rain or irrigation for 2 or 3 days have had less oleocellosis on this variety than formerly.

2. Effects of a High Nitrogen-Low Oxygen Atmosphere on Bananas.

Because of the interest in the use of liquid nitrogen for transit refrigeration and the possibility of having a nearly complete nitrogen atmosphere with little or no oxygen in the transit vehicle, studies were initiated at Beltsville to determine the effects of low oxygen on the fruit. Ripening of green bananas held at 60°F in both 99 and 100 percent nitrogen was retarded. After holding in 100 percent nitrogen for 4 days, bananas ripened slowly in normal air to a dull, yellow color but with normal flavor. After 7 or 10 days in 100 percent nitrogen, bananas ripened poorly or not at all, and were off-flavored. Bananas held in 99 percent nitrogen and 1 percent oxygen for periods up to 10 days ripened in a normal manner with no off-flavor after being removed to normal air.

E. Post-harvest disease control

1. Factors Influencing the Accumulation of Biphenyl in Citrus Fruits and its Effectiveness for Decay Control. California lemons harvested at the B-silver or tree ripe stage decayed more in storage, either with or without biphenyl, than lemons harvested when dark or light green and cured 3 weeks prior to experimental storage.

Biphenyl residue in lemons packed with biphenyl treated sheets rarely exceeded 30 p.p.m. after a simulated overseas transit period (4 weeks) plus a distribution period (2 weeks). All fruit had residues well below the German legal tolerance of 70 p.p.m. Biphenyl residue was 50 to 100 percent higher in lemons held in nonvented cartons than in lemons held in vented cartons under similar conditions. Lemons exposed to biphenyl free air for 1 week at 68°F lost about one-half of the biphenyl absorbed during storage in treated cartons. A report on the results with lemons has been prepared.

The sporulation on California-grown navel oranges inoculated with Penicillium digitatum (Green mold organism) was at least twice as much on fruit in vented cartons with biphenyl sheets as on fruit held under comparable conditions in nonvented cartons. Sporulation was greater on Valencia than on Washington navel oranges held under similar environments, but the nonvented carton was also better than the vented carton for Valencias when biphenyl was used. Sporulation on inoculated navel and Valencia oranges held without biphenyl was appreciably more than on similar fruit held with biphenyl.

Oranges absorbed about twice as much biphenyl as lemons held under the same conditions. Oranges lost biphenyl only one-third as fast as lemons when held in open trays in biphenyl free air after storage.

A method for measuring biphenyl vapor in carton atmospheres was developed. The concentration in vented orange cartons after 1 week at 68°F was 2 to 3 micrograms per liter of air and in nonvented cartons 13 to 33 micrograms. Air saturated with biphenyl at this temperature contains about 50 micrograms biphenyl per liter. The sporulation index was inversely related to the biphenyl concentration.

2. The Incidence and Nature of Biphenyl-Resistance in Lines of Penicillium Digitatum and its Effects on Decay in Citrus Fruits.

About 350 clones of the green mold fungus have been screened for resistance to biphenyl in California. As a result several pertinent facts were established:

- (a) Fungus strains differ markedly in sensitivity to biphenyl vapors, some being extremely sensitive, others inherently tolerant.
- (b) Resistant strains of the fungus are not limited geographically.
- (c) It is possible to separate resistant fungus strains by simple in vitro tests.
- (d) Resistance in strains of the fungus is not necessarily caused by continuous exposure to the fungistat but can be demonstrated in strains never previously exposed to biphenyl.
- (e) The efficacy of biphenyl in protecting packaged citrus fruit against decay and soilage caused by the green mold fungus is not absolute and depends largely on proper holding temperatures.

3. Fungicidal Control of Decay of California Citrus Fruits. 2, 6-dichloro-4-nitroaniline was compared with sodium-orthophenylphenate for control of blue and green molds of citrus. Green mold development was retarded but not eliminated in inoculated lemons dipped in solutions of either material. Mold development was also reduced in lemons dipped in water at 131°F adjusted to pH above 11.5 with potassium hydroxide.

4. Control of Postharvest Diseases of Florida Citrus Fruit. Eleven new fungicides were screened for the control of stem-end rot and green mold of oranges. Two compounds (Dibromotetrachloroethane and Secondary-butylamine) were found sufficiently effective to warrant further testing during the coming season.

Grove inoculations were made at monthly intervals on Partin Delicious oranges and Dancy Tangerines with spore suspensions of the two stem-end rot fungi during the summer and fall of 1961. The incidence of stem-end decay after harvest was considerably increased for both the Phomopsis and Diplodia inoculated fruit over the uninoculated fruit. This shows that these fruit are susceptible to infection by both stem-end rot fungi throughout their growing season.

One hundred twenty-one isolations of green mold (Penicillium digitatum) were made from grove infected citrus fruit collected throughout the citrus area. These were tested for reaction to biphenyl and sodium-orthophenylphenate. Of these cultures, 23 were slightly to moderately resistant to biphenyl and 4 were slightly resistant to sodium-orthophenylphenate. None were immune or even highly resistant to either of these standard fungicides. Hot water (122-131°F) for the control of Phomopsis and Diplodia stem-end rots and green mold showed promising results. Up to 75 percent decay reduction resulted in Pineapple oranges artificially inoculated with green mold or stem-end rot fungi. Less striking results were obtained with naturally-infected fruit. The undesirable feature of this method of control appeared to be the narrow range of time and temperature at which control is affected and physiological rind breakdown (aging and pitting) increased.

Decay, particularly stem-end rot and side rots (Colletotrichum and Phomopsis) increased when fruit was brushed excessively and when there was a delay in washing and otherwise handling fruit following harvest. In general, the longer the delay up to 4 or 5 days, the greater was the amount of total decay and rind breakdown.

In three holding tests conducted during the normal Murcott Honey orange harvest season very little decay or rind breakdown developed during 3 weeks at 70°F. Standard fungicides reduced the decay slightly. This variety apparently has a potentially good shelf life in comparison with other specialty fruits (e.g., tangerines or Temple oranges) which show considerable wastage after 10 days to 2 weeks.

5. Irradiation for Control of Post-Harvest Diseases. (Chicago, Ill) Irradiation of lemons increased the susceptibility of the fruit to sour rot, (Geotrichum candidum). Severe injury to the fruit at or near 200 kilo rad precludes the use of radiation for the control of this disease.

Low levels of gamma radiation delayed ripening of Persian limes but increased stem-end decay (Alternaria citri). Doses of from 25 to 75 kilo rad weakened fruit so that after 3 weeks at 50°F there was an increase in alternaria decay proportional to the gamma dose. Green mold decay (Penicillium digitatum) was neither increased nor retarded by these low levels of radiation. All dosages used retarded yellowing.

Irradiation of Irwin and Sensation mangos with gamma rays retarded ripening. Only the lowest doses, 10,000 rads for Irwin, and 15,000 rads for Sensation, did not impair flavor.

Treatments of 17,000 rads/min. and 37,000 rads/min. for a total dose of 182,000 rads gave complete control of green mold of navel oranges for 7 days. The same total dose given at the rate of 2,000 rads/min. and 12,000 rads/min. was only partially effective.

6. Control of Anthracnose on Mangoes. From preliminary results in Florida, a hot water treatment not exceeding 5 minutes in the range of 130° - 140°F is promising for the reduction in severity of anthracnose in the Hayden variety. Above these temperatures, the fruit scalded. Fruit treated in the mature-green stage is less susceptible to scalding than fruit treated after it has begun turning yellow.

7. New Storage and Market Diseases. Gray mold rot of avocado fruit, apparently previously unreported, has been found on the New York market. The causal organism was isolated and identified as Botrytis sp., probably B. cinerea. The isolate was found to be pathogenic to hard and firm avocados, forming, firm, chocolate-brown lesions that eventually penetrated to the seed cavity.

A pitting disease of bananas caused by Piricularia grisea was isolated from bananas from Chicago and Milwaukee markets. The disease is characterized by small, brown to black, circular, sunken pits which are confined to the skin. Growth of the organism in vitro was slow at 55°F and most rapid at 89°F.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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TRANSPORTATION AND MARKETING FACILITIES
Transportation and Facilities Research Div., AMS

Problem. Returns to producers and prices paid by consumers for citrus and subtropical fruits are adversely affected by the use of inefficient marketing facilities, equipment, and methods. Better work methods, techniques, devices, operating procedures, equipment, and facility designs are needed for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing.

Many of our conventional consumer packages and shipping containers are relatively expensive; require a substantial amount of labor to assemble, fill, and close; are comparatively heavy, hence costly to transport and difficult to handle; are unsuitable for storage; do not adequately protect their contents from damage; fail to make an attractive retail display to stimulate impulse buying; and lose potential sales because of poor visibility provided for contents.

Much of the transportation equipment now in use fails to give adequate protection to the more perishable commodities. Methods of loading often leave the container and product subject to mechanical damage in transit, result in poor utilization of available transportation equipment and hamper effective refrigeration. The substantial savings in labor costs incident to mechanized handling accomplished in other areas are not being realized in agricultural transportation. In the field of air transport, provisions for efficient and economical handling to and from airports and protection against heat and cold are inadequate. In the area of water transportation the arrival condition of fruits and vegetables due to inadequate refrigeration, container, and stowing problems has seriously affected the market for United States products abroad.

USDA PROGRAM

Research on marketing facilities, equipment and methods is a continuing long-range program involving engineering research covering the development of improved work methods, techniques, devices, operation procedures, equipment, and facility designs for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing citrus. The research is carried on by field offices at Gainesville, Fla., and Athens, Ga., in cooperation with the Florida Agricultural Experiment Station, the Agricultural Research Service, Market Quality Research Division of the Agricultural Marketing Service, and commercial packers. The current annual Federal effort devoted to research in this area is 2.6 professional man-years.

Work on consumer packages and shipping containers was in cooperation with the Florida Experiment Station, citrus packing houses, suppliers, and receivers in various terminal markets. The Federal effort devoted to this work this past year was .5 professional man-years.

Research with improved loading pattern in refrigerated trucks and in piggyback shipments and with pallet containers and unitized loads of fresh and processed citrus has been conducted between Florida and northern markets with the cooperation of shippers, railroads, trucking companies and receivers. The Federal effort devoted to this work is 1.9 professional man-years.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

The related research of the State Experiment Stations was not reported by commodities and is included in other reports. Virtually all of the USDA work is done with industry cooperation or participation and involves trade associations, equipment and supply manufacturers, and others mentioned above as cooperators.

Most of these industry members are interested in a wide variety of commodities. Professional man-years involved in their research efforts are not available for specific commodities. For summary statements for research on all commodities, see pages 46-47, 89, and 102-103 in the Transportation and Facilities report.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Handling, Degreening, and Packing Citrus Fruit

This research is directed toward developing improved methods, devices, equipment, and facilities for conditioning, handling and packing citrus fruits in packinghouses at Florida concentration and shipping points.

A manuscript, "Handling Florida Oranges in Pallet Boxes," was prepared by the cooperating personnel, covering the first season's work on the study of the bulk handling of fresh citrus in pallet boxes, as an interim report. Arrangements have been completed to continue this work with another commercial citrus packinghouse.

One special packing line run was made to compare degreening of fruit in pallet boxes with that in field boxes by the percent packout. Twenty pallet boxes (236 field box equivalents) dumped gave a packout of 56.5 percent. Field boxes dumped (492) gave a packout of 45 percent.

Two of the experimental pallet boxes were partitioned to make four separate compartments in each providing different depths (18, 22, and two 26 inches) by means of false bottoms. Two tests were made with tangerines picked into these boxes and then hauled to the packing-house to obtain injury data applicable to this tender fruit. Fruit handled in the pallet boxes showed no more injury than that handled in the field box check lots even for a depth as great as 26 inches.

A wood preservative (Celusan) was tested for its effect on fruit in contact with parts of a treated container. Results indicated that at least one month should be allowed between treatment time of containers and handling fruit in them to avoid "burns" on the fruit.

Sizing experiments were conducted making use of the independently variable speeds for the sizer belts and rolls; available for the first time during 1960-61 season. Premeasured fruit (mixed together) was run through the sizer three times for each of nine different combinations of belt and roll speed. The same test procedure was followed for tangerines, oranges, and grapefruit. Preliminary findings are: (1) There was a substantial difference in sizing accuracy from one run to the next, even when no changes were made in either belt or roll speed; (2) effect on sizing accuracy was greater from changes in roll speeds than from changes in belt speeds; (3) runs made with rolls not turning indicated a possibility for developing a workable belt and roll type sizer without powered rolls, which offers the possibility of building lower cost equipment; (4) speeds of sizing equipment in typical commercial packinghouses are in the range indicated desirable by this research--roll surface speed 50 to 150 feet per minute and belt speed 200 to 400 feet per minute.

Additional time study and other data were obtained on mechanical methods of filling polyethylene bags and cartons and packing bagged fruit into fiberboard master containers. A new bag-filling device for oranges was developed and put into commercial use by one commercial packinghouse. Data indicate that rate of bagging and labor required with this device are nearly the same as with equipment 20 to 30 times more expensive. It should have a forceful impact in reports dealing with bagging methods.

An improved model of the experimental carton-forming fixture for forming two-piece telescoping cartons was made. The output rate was 17 percent higher with this model, and 42 to 75 percent faster than present methods utilizing wood jigs and tables. Arrangements were worked out to install this fixture at one packinghouse for testing during the 1961-62 season. Additional time studies were made of manual packing operations to cover more variations in practice, fruit sizes, and containers. Tests of the device were completed during the 1961-62 season and a manuscript was prepared and submitted for

publication. The device can reduce labor requirements by 35 to 68 percent. Annual savings for packinghouses handling 100,000 cartons per year will vary from \$116 to \$466, depending upon the present method used for forming and assembling cartons.

Equipment was modified and remodeled at the University of Florida packinghouse in connection with the installation of a special chamber for experimental degreening operations. To provide needed instrumentation, dewcels were designed and constructed. An instrument panel and hookup also was constructed for operating the dewcel system. Two series of degreening tests were run using small boxes that simulated pallet boxes. In the first series, two groups of boxes were used, one group with mesh bottoms and one group with slatted bottoms. Air-flow, temperature and relative humidity were maintained in the same range for both groups of boxes. No significant difference in degreening of oranges was observed between the two kinds of box bottoms. In the second series of tests, only boxes with slatted bottoms were used and airflow was varied to obtain three different rates, 35, 70, and 140 cfm. Degreening results were better at the 35 cfm. rate of air-flow.

Preliminary investigations were made to compare two stage packing-house operations with those in the conventional packinghouse.

Work on the handling and degreening of citrus fruits in pallet boxes was continued under a new Memorandum of Understanding with the Brooksville Citrus Growers Association. Following the movement of the AMS pallet box dumper and pallet boxes to the new location, the layout of the experimental equipment was planned and assistance furnished in making the installation. A trash eliminator-flow regulating unit, constructed through the joint efforts of AMS and Brooksville CGA personnel, was connected to the dumper. Degreening and injury evaluation data were insufficient to show whether there was any distinct difference in the results obtained during the 1961-62 season and those obtained with pallet boxes during previous years. Preliminary time study data of the pallet box dumper showed essentially the same results as that obtained at the former location except for pushing boxes into and out of the dumper. With a right angle flow pattern in the new setup, instead of the side-to-side pattern used before, the total time for these two elements was increased because they had to be performed in sequence rather than concurrently. As the handling of pallet boxes by forklift truck was considered to be in a "break-in status" for the small amount of time they were performed, only limited time study data on pallet handling activities with a "ground level" receiving and degreening area were obtained at a new location.

An analysis of different systems of filling small bags with oranges was made and guidelines were developed for the use of commercial firms in planning a bagging system. A manuscript was prepared and submitted for review.

Automatic count-fill machine systems of filling 5-pound polyethylene bags can save a packinghouse up to \$3,200 per year if annual volume is 1,600,000 bags of oranges. Manual bag packing at roll-board or bin-packing stations is still the most economical at low-volume outputs. The savings of the manual system compared to the next least costly system of bagging is about \$500 a year at a volume of 200,000 bags per year.

A channel bag filler, a mechanical device developed and installed at a Florida citrus packinghouse, is the most economical system for bagging at annual volumes of 394,080 to 1,240,320 bags per packing crew.

One study was made on the sizing of tangerines with a perforated-belt sizer in a new packinghouse. Results showed essentially the same sizing accuracy as that found from previous studies on sizing tangerines with similar equipment in another packinghouse built about one year earlier.

B. Cooling Citrus Fruits

One of the most effective ways of reducing spoilage and physiological breakdown of fresh fruits and vegetables during transit is to precool the products prior to shipment. Hydrocooling is the most widely used method for rapidly removing the field or harvest heat of such commodities as peaches, sweet corn, and citrus fruits. This method, however, presents certain problems--particularly in the case of citrus--where detrimental physiological effects sometimes result. Existing methods of hydrocooling are also cumbersome and inefficient. This research is designed to develop improved methods, equipment, operating practices, and techniques for use in existing or new facilities for more efficient precooling of fruits and vegetables.

An experimental forced-air cooling system for citrus fruits was designed and constructed at the University of Florida at Gainesville. This unit is designed for regulating airflow, temperature, and humidity to test the efficiency of forced-air cooling of bulk fruit and to determine the physiological effects of various cooling treatments.

After instruments and test equipment were installed and preliminary test runs made, a series of 126 tests were conducted on specified lots of citrus fruits varying in type and variety.

The results of the tests indicated that forced air precooling of citrus fruits in pallet boxes is feasible commercially. Mass average temperature of oranges averaged 40° to 47° F. after an hour of cooling, of grapefruit, 45° F., and of tangerines, 40° to 43° F. Cooling coefficients based on mass average temperatures ranged from 1.65 to 2.13 for oranges, 1.47 to 1.61 for grapefruit, and 2.08 to 2.47 for tangerines. Loss of moisture over a series (12 tests of a variety) ranged from about 0.5 to 1.0 percent.

C. Consumer Packages and Shipping Containers for Citrus

This phase of the citrus work was undertaken in an effort to stimulate sales of small tangerines and oranges by use of attractive packaging at point of production. Three test shipments of tangerines experimentally packaged in pulpboard tills overwrapped with sparkling shrink film and 5 test shipments of oranges in colorful new 5-pound polyethylene mesh bags were initiated in Florida and examined upon arrival in northern markets. The packages of approximately 20 tangerines were packed 8 to a fiberboard master container. Trade reaction to the packages was favorable at both receiver and retail levels. Some damage to fruit in the top layer apparently was caused by careless closure of the boxes. The tangerines were in excellent condition with a fresh, attractive appearance. In one store the prepackaged tangerines sold as fast as bulk tangerines priced more than 50 percent lower. The 5-pound polyethylene mesh bags of oranges, packed 8 to a full telescope fiberboard box, also received favorable comments from receivers. Breakage of bags was infrequent but one produce manager recommended that they be strengthened.

Other work with citrus was aimed at determining the adaptability of newly developed shrinkable films for prepackaging the fruit in the conventional terminal market operation. Six oranges were placed in a shallow tray, overwrapped with various types of film, and sent through a heat tunnel to shrink the film tight around the fruit. Available machinery and equipment did not handle the films under test efficiently. Packaging specialists helped set up a primarily manual operation which put out slightly more than five packages per man-minute. Suggestions were made for modifications of the machinery and equipment.

D. Loading Patterns for Truck and Piggyback Shipment of Citrus Fruit

Additional research done during the past two years on the new "air stack loading pattern" for corrugated fiberboard boxes has resulted in the development of further refinements of the new pattern. One of the improvements was the modification of the top layer which provides for 84 openings between the boxes in the top layer to permit the circulating refrigerated air to reach the channels in the main body of the load. This change was necessary for shipments made in late-model refrigerated trailers to prevent the cooled air from by-passing of the main body of the load by going down the sidewall flues and providing perimeter cooling only.

The new loading pattern has been adopted and is now used in several thousand over-the-road truck and rail piggyback shipments each season by about 500 Florida citrus shippers. The development and use of the new loading pattern which provides more effective cooling of the fruit shipped in the corrugated boxes has helped stimulate the increased use of these cheaper and easier-to-handle containers. This has resulted in a savings of several hundred thousand dollars per year to Florida citrus shippers in container costs alone.

During the past two years rail piggyback services were made available to Florida citrus shippers and have been used quite extensively. Considerable work was done during this period to help the carriers and shippers solve some problems encountered in adapting the new equipment and service to the handling of citrus. The initial results of this phase of the work was summarized in a recently released interim report.

E. Pallet Shipments of Citrus

During the past two years several tests were also made with pallet container shipments of oranges and grapefruit from Florida to northern markets. Although potential savings that might be derived from shipping these products in pallet containers as compared with shipping them in smaller conventional containers are not as large as in the case of apples they are still substantial. An interim report on this work is now being prepared for publication.

NOTE. For additional information on research of a general or cross commodity nature in this area, see the Transportation and Facilities Research Division report.

F. Unitized Loading of Canned Citrus Juices

During the past year a new railroad piggyback trailer equipped with a modular-grooved aluminum alloy flooring to facilitate loading and unloading of unitized loads by the multi-fork system without pallet was made available to AMS for shipping and handling experiments through the cooperation of a major southeastern railroad, a trailer manufacturer and the flooring manufacturer. Only one test shipment of canned citrus juice was made with the new equipment and handling system late in the 1962 season. Although the system appeared to work fairly smoothly in some respects, a few major difficulties were encountered. It is still too early to appraise the results of this exploratory work.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Handling, Degreening, and Packing Citrus Fruit

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Improvement of Specific Features of Rail and Truck Equipment

- Guilfooy, R. F. 1962. Refrigeration in the Transport and Local Delivery of Citrus Concentrate. Address before the Annual Meeting of the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) in Miami, Florida.

Loading Methods

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IV. ECONOMIC RESEARCH

ECONOMICS OF MARKETING

Marketing Economics Division, ERS

Problem. Most agricultural processing industries are experiencing rapid and drastic changes in their market organization and practices. These changes are affecting both farmers and consumers. Research is needed to keep abreast of such changes and to indicate their probable consequences. There have been substantial advances in recent years in increasing efficiency and reducing costs through adoption of new technology in producing, assembling, processing, and distributing farm products. However, for producers and marketing firms to remain competitive additional information is needed on margins, costs, economics of scale and efficiencies possible in the marketing of farm products.

Marketing research also is increasingly concerned with evaluating present and prospective programs pertaining to agriculture, such as the Food Stamp Program and Federal Grading Activities and to the changing structure of market industries as this may influence the bargaining power of farmers. Research also is being directed to the economics of transportation and storage activities of both private firms and government. Increasing attention is being given to the longer-term outlook for various products and markets as an aid in better assessing the prospects for increasing industrial employment under the Rural Development Program and in assessing prospective interregional shifts in the areas of production and marketing for specific products.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural economists, economists, and personnel with dual economic and technical training engaged in research to determine the reasons for the changes that are taking place in marketing so that ways can be found to increase the efficiency of the marketing system and make it more responsive to changing public needs. This research covers all economic aspects of marketing from the time products leave the farm until they are purchased by ultimate consumers. It includes work on market potentials for new products and uses cooperative with the Hawaiian Agricultural Experiment Station and Utilization Research of ARS; on merchandising and promotion in cooperation with the Florida Citrus Commission and chain store retail outlets in Cleveland and Philadelphia; on marketing costs, margins, and efficiency in cooperation with citrus packinghouses; and on market structure, practices, and competition with the cooperation of Florida and Texas Experiment Stations, grower-shippers, terminal market handlers, supermarket operators in Grand Rapids, Michigan, and the wholesale market trade in the 58 markets being studied throughout the United States: 5.8 Federal professional man-years were involved in F.Y. 1962.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Most of the Experiment Stations in the citrus and subtropical fruit growing states devote research resources to investigating various of the phases or areas in the field of economics of marketing, but information is not available by commodities on the professional man-years involved. The same situation holds true for the research by industry in this field.

Industry and other organizations including food manufacturers, industrial firms, producer associations and State agencies conduct or sponsor important research on new products and new uses. Most food manufacturers regard market potentials research as a necessary adjunct to their research and development programs for new food products. Among those industrial firms which process and market agricultural products most key firms have or retain competent research and development organizations. Results of these market research efforts mostly are kept confidential. Several producer associations sponsor research on development of new food products and contribute to the early stages of commercial trial and evaluation of these products. Notable in this area is the Florida Citrus Commission.

Research on merchandising and promotion of citrus and subtropical fruit is in progress in Florida, Texas, Puerto Rico and Hawaii. Industry and other organizations including voluntary producer-promotion groups; commissions, councils, boards, etc., established under enabling legislation; wholesalers and retailers; processors and distributors; State Department of Agriculture, and individual proprietors, also conduct some research on merchandising and promotion. Both private firms and agricultural promotion groups do contribute to public research in this area by cooperating with the Department. They provide facilities (which are essentially laboratories), personnel, office space and economic data to the USDA program. The agricultural promotion groups cooperating with the Department finance all merchandising and promotional cost involved in cooperative research studies and frequently contribute financially to the research by defraying part of the cost of collecting data.

The Florida Station is conducting research on demand, costs, margins and efficiency of handling citrus. The amount of research conducted by private firms on marketing margins, costs and efficiency of handling citrus and subtropical fruits is not known but it probably is small.

Many of the Experiment Stations devote considerable research resources to investigating the market structure and practices for the various fruits and vegetables in many producing areas. A description of current practices provides a basis for knowing where inefficiencies are and what obstacles exist to improvement of marketing practices. Another phase of this research deals with the effects which changing technology and practices have upon the availability of markets and returns to the grower.

An example of these projects is the study of how large-scale retail buyers operate, what they will expect of farmers in terms of commodity specifications, and marketing services, and how farmers may be compensated for performance of services, previously the responsibility of other sectors of our production-marketing system. Another element of these studies is the determination of processing and packaging plant location in relation to economy of size of producing area.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Market Potentials for Hawaii Farm Products. Research in cooperation with the Hawaii Agricultural Experiment Station has been initiated to determine the economic feasibility of broadening the base of Hawaiian agriculture by developing new markets for diversified Hawaii products such as macadamia nuts, and fruits and juices. Market tests will be conducted to introduce Hawaiian products in new markets, to ascertain their acceptability and salability and to provide estimates of potential demand to guide market development efforts. Marketing and merchandising practices will be evaluated to determine improvements required for full exploitation of market expansion possibilities.

Economic Impact of Freeze-Drying. New technology can have tremendous consequences and their impacts need to be evaluated with special reference to costs, market structure, labor demand and utilization, capital needs, and market demand. Freeze-drying is an emerging technology of possible major import which requires study to ascertain its place and impact in the marketing system. Since initiation of this newly formed industry, a test panel for existing commercial products was established with the cooperation of ARS at Beltsville. Also, with the cooperation of plants either commercially processing or experimenting with commercial pilot operations, and from representatives of equipment companies, data has been gathered which will form a basis for a synthetic projection of what costs may be anticipated with model plants constructed in the following sizes: 4 tons, 8 tons, 16 tons, and 32 tons of water removable ability for a 24-hour period. Work has been initiated to use such engineering synthetic cost data to estimate the impact of freeze-drying upon food processing industries and in the process to estimate the long-run potential of the freeze-dry industry.

The taste panel work covered approximately 30 freeze-dry products now on the market. Comparisons of current frozen and canned products of standard quality were used as a frame of reference for the testing of the prepared freeze-dried foods. Preliminary results suggest many of the products are satisfactory from a taste standpoint. However, a few appear to be unsatisfactory.

Preliminary estimates imply that the cost per pound of water removed will approximate 7 cents for a low volume capacity operated plant, and about $3\frac{1}{2}$ cents for a large capacity operated plant. A full report of the engineering synthetic costs should be ready for publication during the fiscal year.

Market Potentials for New Products and Uses -- Liaison Between ERS and Utilization Research, ARS. An agricultural economist is stationed at each regional Utilization Research and Development Division to provide liaison between the regional laboratories, ARS, and the Economic Research Service in order that economic research may be teamed with physical science research in approaching problems relating to new products and new uses. Phases of work are as follows: (1) to delineate the economic problems involved in developing markets for new and extended uses of commodities on which the laboratories are working; (2) to develop and assist in carrying out research studies for providing information that would aid the laboratories in deciding what particular products or processes would be most likely to be economically feasible; and (3) to develop and assist in carrying out research studies for appraising new products and processes developed by the laboratories, including studies of market potentials, comparative costs, and studies of the probably impact of new developments on sales and farm income.

Merchandising and Promotion. Studies have been conducted to: (1) determine the long-term effect of advertising and promotion for Florida oranges and grapefruit. The analysis covers the period 1921-22 to 1960-61, excluding the World War II period 1942-1946. The findings indicate a succession of positive shifts of the sales-price relationship for oranges during the period analyzed. For grapefruit positive shifts of the sales-price relationship were observed prior to World War II, but a negative shift after the war. The shift of the sales-price relationship for oranges appears to be associated with advertising and promotion efforts, and special demand creating conditions, such as, introduction of new products and changes in distribution which were supported by relatively intense promotional activity. Shifts observed for grapefruit were also associated with these factors prior to the war. The negative shift after the war appears to be the result of competition from frozen orange concentrate. The market position of grapefruit vis-a-vis oranges appears disadvantageous because of the relative consumer acceptance of concentrated juices.

(2) Evaluate the effect of the special promotional campaign for frozen orange concentrate conducted during the fall of 1959 on retail sales of frozen orange concentrate and the on tree prices received by growers for oranges. In the analysis sales increases and estimated increases in revenue were related to the investment connected with the special campaign. The findings of this study shows that average monthly sales were about 13 percent higher than could have been expected at prevailing prices without the promotional effort. The gross revenue from sales of frozen orange concentrate at the retail level from September 1959 through March 1960 was estimated to be about \$18 million greater than it would have been if prices had been reduced sufficiently to sell the same volume of juice. The findings also indicated that on tree prices received by growers during the 1959-60 marketing season were from 30 to 50 cents per box higher than would have been received

if the price of frozen orange concentrate had been reduced to move the same quantity of juice.

(3) Consumer acceptance of fresh Florida oranges relative to the presence or absence of a color additive was determined. This study involved controlled experiments in selected retail food supermarkets located in Cleveland, Ohio (representing markets in which consumers were generally acquainted with color-added but not natural color Florida oranges), and in Philadelphia, Pennsylvania (representing markets in which consumers were acquainted with natural color Florida oranges). Sales of Florida oranges decreased significantly, 20 percent, in Cleveland when only natural color oranges were offered. In Philadelphia, no difference was found in sales of Florida oranges when natural or color-added fruit was offered alone. In both cities, sales of Florida oranges increased significantly, 36 percent in Cleveland and 20 percent in Philadelphia, when combination displays of color-added and natural color oranges were offered. These results indicated that a significant number of consumers do not purchase fruit of poor appearance with respect to color, while others do not tolerate additives to improve the color.

(4) Analyze trends and shifts in availability and consumer purchases of citrus and competing products. Data with brief analysis, are compiled and published in periodic reports. Monthly reports include: volume of purchases, proportion of families buying, average size and frequency of purchase, and average retail price. Annual reports give information by region, size of community, and family characteristic, such as income, presence and age of children, occupation and education of family head, and by age and employment status of housewife. These data are obtained from a private research organization under contract with the Florida Citrus Commission, which, with some help from the California Prune Advisory Board, pays the entire contract cost. The Department analyzes the data, prepares and distributes the reports. Among the findings are indications of losses of market among young and middle age families that offset gains among older families; declines in consumption rates among heavy buyers that offset gains among light buyers; shifts in use to new products and flavors; and failure of use of frozen orange concentrate to keep pace with the growth of population.

Costs of Handling Oranges from Orchard to Packing Plants. Findings of a study of certain costs in marketing citrus fruits show that the pallet box method of handling oranges from orchards to packing plants is cheaper than the traditional field box method at all seasonal volumes and at all weekly operating rates. For example, at an annual volume of 500,000 field boxes, savings of \$23,400 per year are possible with pallet box handling compared with field boxes.

Market Structure, Practices, and Competition. The wholesale fruit and vegetable business is a static industry in the midst of a dynamic economy. The total volume of fresh fruits and vegetables for off-farm civilian consumption increased 12 percent from 1935-39 to 1957-61, while the total volume of all food was increased nearly 60 percent. Direct buying from shipping points by chains and other retail organizations has increased sharply, and the total volume of business of wholesalers has declined. The number of major wholesalers is declining. These changes in structure create severe strains within the industry both at the wholesale and the shipping point level. Their impacts on farmers, in terms of the demands for their products (quality, uniformity, packaging, quantity, etc.) are marked. Wholesalers, packers and shippers, and farmers will find it increasingly necessary to make adjustments to the different types of buyers with whom they must deal and their requirements.

A study of market structure and performance of the lower Rio Grande Valley fruit and vegetable market was initiated in August 1961. Detailed information on prices paid and prices received during the 1960-61 season were obtained from a stratified random sample of 32 shippers in the Valley.

Two approaches were used in the study of competitive practices in marketing Florida and Texas grapefruit. One was to determine if price differentials existed between comparable types of grapefruit at the wholesale level. After much price data were collected and tabulated in preparation for analysis, it was found that the lack of information for comparable types of grapefruit and for certain time periods precluded the analysis. This approach was then abandoned.

The second approach was a survey of terminal market handlers of grapefruit to determine buying and handling practices and, also, to determine to what extent buyers believe that quality of grapefruit is related to the State in which it is produced. A survey was conducted and personal interviews obtained from 165 handlers in eight terminal markets where Texas and Florida grapefruit compete.

During April and May 1962, experimental tests were conducted in nine supermarkets in Grand Rapids, Michigan, to determine the demand and substitution relationships for citrus both in the fresh and processed form. The objective of these tests was to generate data with which demand and substitution relationships for Florida and California Valencia oranges could be established. The analysis is underway.

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IMPROVING MARKETING OPERATIONS THROUGH
RESEARCH WITH FARMER COOPERATIVES
Marketing Division, FCS

Problem. Farmers, in marketing their production, face a revolutionary change in terms of market organization and marketing practices. The ever increasing and important supermarkets require large quantities, good quality, and frequent delivery which the small farmer, working alone, or a cooperative, or local firm of limited size cannot supply. Cooperatives must find ways to consolidate volume, either through internal growth, merger, acquisition or federation to help them meet the needs of mass merchandising. Ways must also be found to reduce marketing costs by increasing efficiency through improved operations, better organizations, and more mechanization.

Farmer cooperatives are an important part of the distribution system and represent a major potential for meeting the farmers' marketing problems in the modern distribution system. They are organized and operated to increase farmers' net income. Through cooperatives farmers seek to increase their bargaining power; obtain needed services at cost; improve the quality of farm products; and obtain a larger share of the consumer's dollar. Cooperatives face many problems in achieving these objectives. Research is needed which will assist marketing cooperatives, as well as other marketing agencies, solve their problems by making available essential factual information and developing practical and useful operating plans and procedures.

USDA PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operations, and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms.

The number of Federal professional man-years involved in this work for all commodities totals 24.8, of which 1.4 are devoted to citrus and subtropical fruit.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

In 1961 the California Agricultural Experiment Station worked on determining the characteristics of demand for Calavo avocados.

The majority of the research work of marketing cooperatives is in the area of merchandising and promotion, although some cooperatives are studying feasibilities of having products graded and packed on the farm. Some farm supply cooperatives have formalized economic research departments, and part of their programs are concerned with the marketing of farm products. A few cooperatives now have employed management consultants to study and advise them on organizational and personnel problems.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Coordination of avocado marketing. To provide growers and shippers in the Florida avocado industry with basic information on which to make marketing decisions, a statistical analysis was completed of economic relationship affecting the industry's competitive position, including sources of supply, utilization and consumption, distribution of sales, and prices. Recommendations, based on this analysis, related to production and marketing information, advertising and sales, promotion, quality control, and coordination of sales. A report has been prepared for publication.

Improving operating methods. To provide information on methods of improving sales operations, research was completed on possibilities and problems of various joint sales programs that might be used by fresh citrus shippers in Florida. Interviews with 120 shippers showed that 7 out of 10 saw a need for more joint sales activity. About half of the shippers not affiliated for fresh sales purposes were willing to participate in some form of joint sales activity. Shippers saw market and price stability as the most likely result of more joint sales activity. Independence of shippers was considered to be the chief obstacle to more coordinated sales efforts. The study also pointed out legal obstacles to joint sales efforts that are not grower oriented.

Direct marketing to large buyers. To provide growers and shippers with guidelines that will help them adapt to changing marketing conditions, research is underway to determine the nature and extent of large scale buyers' requirements - particularly those made on a specification basis - for Florida fresh citrus.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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ECONOMIC AND STATISTICAL ANALYSIS
Economic and Statistical Analysis Div., ERS

Problem. Adequate and accurate information is needed on supplies, production and consumption of farm products, and the effects these and other factors have on the prices of agricultural commodities. Such information is needed in planning operations for the producers, processors and distributors and also benefits the consumer in selecting his purchases. Similarly accurate quantitative knowledge of the inter-relationships among prices, production and consumption of farm products are needed by Congress and the Administrators of farm programs to effectively evaluate current and future price support and production control programs.

Due to the instability of the prices he receives, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The farmer needs to be provided with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook intelligence and the development of longer range projections of the economic prospects for the principal agricultural commodities.

USDA PROGRAM

The outlook and situation program involves continuous appraisal of the current and prospective economic situation of citrus fruits. The regular appraisals are supplemented by special analyses when needed. Results of these appraisals, findings of special analyses, and long-time series of basic data are published in the Fruit Situation, issued 4 times a year, and in brief reviews in quarterly issues of the National Food Situation and the Demand and Price Situation. A comprehensive analysis of the citrus fruits situation is presented at the Annual Outlook Conference. Outlook presentations are also made at regional or State outlook meetings, meetings of farm organizations, and to various agricultural industry groups. Special studies are made from time to time to determine probable effect of proposed programs on supply, price and consumption of citrus fruits. Basic statistical series on stocks, foreign trade, consumption, and price are compiled, improved and maintained for general use in statistical and economic analysis. This work involved .5 professional man-years in Washington.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Research of State Experiment Stations in this area is not reported separately but is included with research reported under related areas.

A substantial number of private organizations--including manufacturers of food and fiber products, private commodity analysis, banks and investment houses--are engaged in commodity outlook work similar to that carried on by USDA. This work, however, frequently relates to shorter time periods than those covered by the Department's outlook appraisals; is predominately for private use; and not available to the public.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

The 1961-62 citrus crop was a record, 13 percent above 1960-61 and 10 percent above average. Current indications for 1962-63 point to another large citrus crop. Prospects are most favorable for oranges and grapefruit, least favorable perhaps for lemons.

About 81 percent of the record 1961-62 Florida orange crop was processed. Output of both canned single-strength juice and frozen concentrate was up considerably, that of the latter topping by 38 percent the previous record in 1960-61. Current stocks of these and other citrus juices are much larger than a year ago, despite increased movement. Retail prices are below a year ago.

Grower prices for the larger 1961-62 citrus crops generally have averaged below prices for the 1960-61 crops. However, prices for California oranges, of which production was down, frequently averaged above 1960-61 prices. Following the freeze damage to the Texas citrus crops in January 1962, prices for Florida pink seedless grapefruit increased to levels above comparable prices in the first half of 1961.

A study of trends in citrus production and use since 1935 revealed the following developments: (a) a rising trend in total production of citrus fruits; (b) increased dominance of Florida as a producer of oranges and grapefruit; (c) increased emphasis in processing, and (d) shifts in consumption from fresh to processed items, especially frozen orange concentrate.

A similar study of postwar trends disclosed that per capita consumption of fresh and processed citrus fruit (fresh equivalent basis) during the 1950's did not change greatly in level but that consumption of fresh declined substantially while that of processed, especially frozen concentrate, increased an offsetting volume. Processed surpassed fresh in 1954 and in 1960 comprised about 61 percent of the total.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION--
HOUSEHOLD AND INDUSTRIAL
Standards and Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for the consumer to express to producers either his pleasure or displeasure with available merchandise. In order to market agricultural products more efficiently, we need to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on preferences, levels of information or misinformation, and satisfactions or dislikes of both present and potential consumers. We also need to know consumer attitudes toward the old and new product forms of agricultural commodities and their competitors, and probable trends in the consumption of farm products. We need to know the relationship between agricultural and nonagricultural products and the relationship of one agricultural commodity to another in consumers' patterns of use. Producer and industry groups and marketing agencies consider this information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increase returns to growers.

USDA PROGRAM

The Special Surveys Branch of the Standards and Research Division conducts applied research on representative samples of industrial, institutional, or household consumers and potential consumers, in local, regional, or national marketing areas. Such research may be conducted to determine: attitudes, preferences, buying practices, and use habits with respect to various agricultural commodities and their specific attributes; the role of competitive products, and acceptance of new or improved products.

The Special Surveys Branch also conducts laboratory and field experiments in sensory discrimination of different qualities of a product. These studies ordinarily relate discrimination to preferences and attitudes as they influence purchases in order to assess the standards of quality, packaging, etc., which are needed to satisfy consumer demands.

The work of the Branch is carried out in cooperation with other Federal governmental agencies, divisions within the Department of Agriculture, State Experiment Stations, Departments of Agriculture, and land grant colleges, agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff, with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology and other social sciences, in Washington, D.C., which is headquarters for all of the survey work whether it is conducted under contract or directly by the Branch.

The Federal scientific effort devoted to research in this area during the past year totaled 7.0 professional man-years, of which 1.3 was devoted to work on citrus and citrus products.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Agricultural Experiment Stations. The Stations do not report any of their work under this heading. However, they do have a considerable program in the area of consumer buying and use practices and motivation and decision making. This includes some research in preference and quality discrimination. There is a reference to parts of the Stations' program in other division reports.

Industry and Other Organizations conduct research in this area, but the research done by individual firms and organizations is almost without exception for their exclusive internal use. There are very few instances in which the findings are made public or made available for government reference. In addition to the research actually initiated and paid for directly by industry, a substantial amount is undertaken in their behalf as part of the service provided by their advertising agencies.

Producer Groups. A number of food producer groups conduct consumer preference work with their own staff and, in addition, contract for research with private marketing firms. To a large extent, this research is limited to food classes such as poultry, dairy products, citrus and deciduous fruits (rather than being directed to individual branded products). This research ranges from a small to national coverage. It includes taste testing for quality differentiation, new product acceptance, and attitudes toward existing products.

Food Processors. In the livestock industry most of the larger packers have research programs for evaluating the effect of product change and acceptance of new meat products. A sizeable number of other food processors have extremely large programs of consumer research. They are engaged in work on new food forms and convenience foods such as cake mixes, canned and frozen fruits and vegetables, deciduous fruits, citrus fruits, soups, dairy products, and alcoholic beverages.

Miscellaneous Groups. There is a smaller but constant amount of research undertaken by magazines and publishing houses for their principal advertisers. A number of the largest retail stores in our major cities study the consumers' reactions to their merchandise and service by conducting interview studies with customers and noncustomers. One of the largest food retailing chains has an active program in quality research which involves taste testing as well as consumer preference. Estimated annual expenditures for research related to agricultural commodities and nonagricultural products in competition with them are equivalent to approximately 20 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

About one-third of the Florida oranges marketed for fresh consumption are sold in their natural-color state, principally in Eastern states. Midwestern states receive primarily color added fruit. In order to test the acceptance of natural color fruits, three-phase surveys were done in one Midwestern and one Eastern city, in cooperation with Economic Research Service, measuring opinions of and attitudes toward natural versus color added fruit. Nearly three-fourths of the orange purchasers interviewed at side-by-side displays of color added and natural fruit knew of the practice of color addition. Nearly half said that it made no difference to them, the remaining purchasers being divided on whether it was a desirable or undesirable practice. The majority, however, indicated that they would have purchased oranges whether or not color had been added, suggesting that, while some buyers disapprove of the practice of adding color to oranges, their attitude is tempered by the belief that the color does not effect the eating quality of the fruit. This study of citrus fruit has been completed and a report published.

To aid Florida citrus processors in determining the most desirable sugar-acid levels in packs of canned single-strength citrus juice for export and in understanding attitudes of European consumers toward use of citrus products, a consultant was made available by the Special Surveys Branch to set up an experiment in taste testing and a household survey in West Germany.

Planning was begun on a study on citrus fruit to be conducted in one city to determine what external characteristics consumers actually consider desirable and undesirable when they are purchasing fresh oranges or grapefruit. This information will be compared with the opinions of producers and wholesalers about what consumers want and look for when they are purchasing fresh citrus fruit. One of the long-standing problems of fruit producers has been that they receive lower prices for fruit which wholesalers believe has defects that are objectionable to retail consumers. To what extent these beliefs are founded on fact is the subject of this inquiry.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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V. NUTRITION AND CONSUMER-USE RESEARCH

Human Nutrition Research Division, ARS
Consumer and Food Economics Research Div., ARS

Problem. The assortment and characteristics of foods available to consumers are constantly changing with the adoption of new production, processing, and marketing practices. Constantly changing also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help carry out the Department's responsibility to advise on the quantity and variety of foods that will assure maximum benefit and satisfaction to consumers, continuous research is essential on the nutritional requirements of persons of all age groups, and on the nutrient and other inherent values of foods and how to conserve or enhance these values in household preparation and processing. Periodic examinations of the kinds and amounts of foods consumed by different population groups and individuals also are essential for evaluation of the nutritional adequacy of diets and to give the guidance needed for effective nutrition education. Such information provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and use.

USDA PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care, and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition education programs.

The research is carried out by two Divisions of the Agricultural Research Service--the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done in Washington, D. C. and at Beltsville, Maryland; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas totals 61.1 man-years. It is estimated that approximately 4.1 Federal professional man-years are utilized in studies related to citrus and subtropical fruits.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and micro-organisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research is described on a nutrient basis in the report for the Food and Nutrition Advisory Committee. The total Federal effort is 29.5 professional man-years.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Station research in 1961 included 22.4 professional man-years devoted to studies of the inherent properties of foods and of their household use; 17.6 to analyses of a variety of foods for vitamins, various lipid and protein components, and minerals; and 2.7 to studies of food consumption and dietary levels of households and of food management practices. Although the State work has not been reported on a commodity basis, some of the above research is applicable to this report.

Industry and other organizations such as universities and professional organizations are estimated to devote about 36 man-years to research on the preparation of materials for nutrition education, surveys of diets of individuals, and studies of functional properties and stability of food and of their specific nutrient contents. Limited work is done on the amount and structure of nutrients in foods and on compiling food composition data. Again, some of this work is applicable to this report.

REPORT OF PROGRESS OF USDA AND COOPERATIVE PROGRAMS

A. Nutritive Values of Foods

1. Tables of Food Composition. Data review has been completed for a revised edition of Agriculture Handbook No. 8, "Composition of Foods.. Raw, Processed, Prepared." This edition will have nearly 2,500 food items as compared with 751 items of the preceding edition, and upwards of 45,000 separate compositional values. For many foods, data will be provided for different forms--raw, cooked, canned, frozen, milled, dried, instant, dietetic, etc. The new publication will have, in addition to other constituents, data for protein, fat, carbohydrate, five vitamins (vitamin A, niacin, riboflavin, thiamine, ascorbic acid), six minerals (calcium, phosphorus, iron, sodium, potassium, magnesium). Explanatory notes for foods and nutrients will be added for users of the tables. Information on cholesterol and fatty acids will also be included.

Data for about 40 citrus and subtropical fruits will be included in the new edition of Handbook 8. For many of these foods, sufficient data were available to permit classifying by variety or type, market form--raw, canned, frozen, juice, pulp--or other characteristic. The total number of citrus and subtropical fruit items for which data will be included in the revised Handbook 8 will be close to 140.

2. Vitamin Analyses. Values more representative of the vitamin B₆ content of foods now may be obtained by use of a method recently developed at Beltsville, Maryland. Separation by column chromatography of the three forms of vitamin B₆ naturally occurring in foods permit each form to be assayed individually. Values derived from these data for total vitamin B₆ approximate closely values obtained from rat bioassay.

Research is in progress to combine a number of steps in the determination of various B-vitamins in order to facilitate their simultaneous analyses, permit complete characterization of the B-vitamins in foods and to determine their overall distribution in the food supply.

Avocados averaged 2.3 micrograms of vitamin B₆ per gram, about 50 percent of which was pyridoxal. California oranges averaged 0.9 micrograms, over half was pyridoxal; and grapefruit, 0.3 micrograms per gram, largely pyridoxine and pyridoxal. The studies will include other fruits.

3. Mineral Analyses. Avocados, bananas, grapefruit, lemons, limes, mangos, oranges, pineapples and tangerines are included in the 66 lots of citrus and subtropical fruits collected for determination of mineral element content. At least four lots of each fruit from its major production area or areas for fruits available on the Washington, D. C., market have been procured. Preparation of all samples for analysis is complete, and element analyses are more than half complete.

4. Proximate Composition. Determination of the proximate composition of foods, i.e., moisture, fat, kjeldahl nitrogen and ash, were carried out in conjunction with studies for other nutrients in foods such as the vitamins, mineral elements, fatty acids and carbohydrates. Such an arrangement added to the information on composition of foods in the various commodity groups and also permitted the calculation of nutrients on a fat free-moisture free basis or on a nitrogen or protein basis where relationships among nutrients were concerned.

Moisture, total sugars, reducing sugars, sucrose and total titratable acidity were determined in the following sample lots: 12 orange, 4 tangerine, 5 lemon and 11 banana. These are part of the fruits obtained from different production areas for mineral element analyses. The studies are continuing.

B. Food Properties Related to Quality and Consumer Use

The quality, serving yield and preparation time of fresh, canned and frozen citrus and subtropical fruits were obtained as part of a co-operative study with the Economic Research Service where determinations were made of comparative costs per serving of different market forms. Fruits included in the study were: Fresh - grapefruit, lemons, oranges and pineapples; Canned - orange juice, lemon juice, pineapple chunks and pineapple slices; Frozen - grapefruit sections, orange juice concentrate and pineapple chunks. Results of the study are being incorporated in a technical publication covering citrus, subtropical and deciduous fruits. Information on additional samples of the frozen fruits was obtained to serve as a base for planning studies on household handling of frozen foods. Frozen grapefruit sections, orange juice concentrate and pineapple chunks were purchased in four consecutive seasons in several Washington, D. C., retail markets. Taste panel, chemical and physical measurements were used as quality criteria. Good pre-purchase storage history for the samples was indicated by a low proportion of oxidized to reduced ascorbic acid and low values for solids-to-liquid ratios of titratable acids in frozen grapefruit and pineapple and by cloud data in frozen orange juice.

C. Food Economics and Diet Appraisal

1. Food Consumption and Dietary Levels. Information on the nutritive value of the food consumption of households based on the 1955 survey data has been summarized in Report No. 16 of the 1955 Household Food Consumption Survey series. Average family food supplies for a week in 1955 were sufficient to provide more than the National Research Council's recommended allowances for calories and eight nutrients for which values were calculated. However, many households (48 percent) had diets that did not fully meet the allowances in one or more nutrients. Other analyses of survey data show the relation of family size, the education of the homemaker, and of income to the food consumption of households. Because of interest in information on quantities of foods used by high consumers as well as average consumers estimates were made for some 60 food items of the ninth decile--the figure dividing the highest 10 percent of the consumers from the lowest 90 percent. For fresh citrus fruits the amount consumer per person in "high consumption" households was nearly 3 times as much as "average consumption"; for canned citrus the ratio was nearly 4.0.

Two surveys were conducted cooperatively with the Marketing Research Division, Economic Research Service in Detroit, Michigan and Fayette County, Pennsylvania to provide evidence on the extent to which food consumption is increased and diets improved as a result of the Food Stamp Program.

A report of the food consumption and dietary levels of a group of older, low-income households in Rochester, New York is in preparation.

Work is being undertaken on food consumption and nutritive content of diets of individuals. A systematic review and summarization of quantities of food consumed is being made through a cooperative agreement with the Minnesota Agricultural Experiment Station. A similar review of the nutritive content of the diets of individuals is being made by Washington staff.

The nutrient content of the per capita food supply, calculated each year, using data on retail weight quantities of food as developed by the Economic Research Service, provides the only source information on year-to-year changes from 1909 to date.

2. Food Management Practices. Information on the kinds, amount, and nutritive value of foods used and discarded in households has been obtained in a series of small studies. Results will help to evaluate survey data on household food consumption.

A report on household practices in handling and storing of frozen food has been prepared, based on surveys in Baltimore, Maryland, and Indianapolis, Indiana. Households provided information on the length of time frozen food was held in home storage, and the temperature of the compartment in which frozen food was being held at the time of the interview.

3. Development of Food Budgets and Other Basic Data for Food and Nutrition Programs. An important aspect of nutrition research is the interpretation and application of research findings to practical problems of food selection in relation to health. An ongoing program of work includes assembling and interpreting available information on nutritional needs, food consumption, and nutritional value of foods for use by nutritionists, teachers, health workers, and other leaders concerned with nutrition education programs.

A technical report explaining the development of the food budgets, "Family Food Plans and Food Costs," has been completed and is in press. Another in the series of popular publications on food management has been prepared, "Food for the Young Couple." A publication, "Family Food Budgeting...for good meals and good nutrition," designed to help families of all sizes is also being prepared.

Regular pricing of family low-cost, moderate-cost, and liberal food plans is published in Family Economics Review on a quarterly basis for the U. S. average and on an annual basis for the regions and the low-cost food plan for the South. Each plan gives suggested quantities of food that will meet nutritional needs for each of 17 age and sex groups and for women during pregnancy and lactation so that household or population totals may be obtained.

Nutrition Committee News, a bimonthly periodical prepared for members of State nutrition committees and other workers in nutrition education provides a channel for disseminating pertinent information and for reporting nutrition education activities. A Nutrition Education Conference sponsored jointly by USDA through its Nutrition Programs Service and by the Interagency Committee on Nutrition Education was held in Washington, D. C., January 29-31, 1962.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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